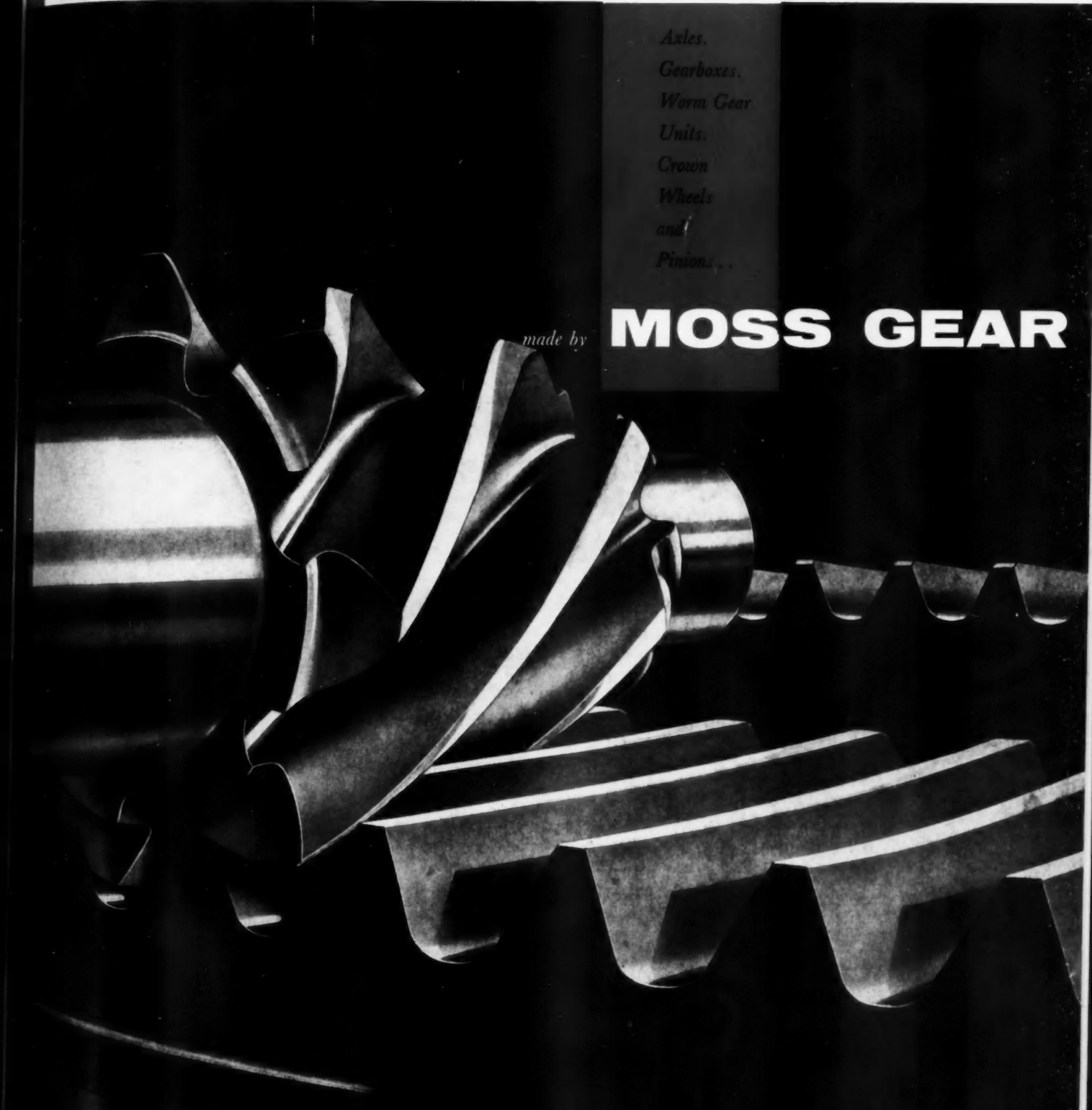
THE ENGINEER

JANUARY 27, 1961 | 28 ESSEX STREET, STRAND, LONDON, W.C.2 | TWO SHILLINGS

THE UNIVERSITY OF MICHIGAN
MAR 8 1961
ENGINEERING LIBRARY

Axles. Gearboxes. Worm Gear Units. Crown Wheels and Pinions . .

made by **MOSS GEAR**



THE MOSS GEAR CO. LTD · CROWN WORKS · TYBURN · BIRMINGHAM · 24

Telephone: ERDington 1661/6. Telegrams: 'Mosgear Birmingham'.

SCRAP for COHEN'S

COHEN'S for SCRAP

GEORGE COHEN
SONS AND COMPANY LIMITED

THE 600 GROUP OF COMPANIES

RAW MATERIALS DIVISION

Experts in Scrap since 1834

WOOD LANE, LONDON, W.12. · *Telephone:* Shepherds Bush 2070 · *Telegrams:* Coborn, Telex, London

And at 600 Commercial Road, E.14 · Canning Town, E.16 . Southall, Middlesex · Bath · Belfast · Glasgow · Hebburn · Kingsbury
Leeds · Luton · Manchester · Middlesbrough · Sheffield · Southampton · Swansea · Brussels · Dublin · Mombasa · Nairobi
New York · Sierra Leone · Singapore · Takoradi

Enter No. C2 on reply card

THE ENGINEER

Established 1856

No. 5479 **JANUARY 27, 1961** VOL. 211

EDITORIAL CONTENTS

Leading Articles

International Rocketry 105
Commonwealth Communications 105
Pressure Vessel Design 106
British Shipping and Future Prospects 106

Articles

100 Years Ago 107
Consett Plate Mill 108
"Minitrack" Station at Winkfield 111
Fessler, Hay and Roberts Centrifugal Stresses at the Bores of Wheels 113
J. Waldersee Natural Frequencies of Large Seismic Mountings on Non-Coplanar Isolators . . 115
J. Starczewski Graphical Design of Tubular Heat Exchangers 116
M. J. Allday The Training of Industrial Process Workers 117
Progress of the Metropolitan Water Board's New Works 121
Welded Boilers and Pressure Vessels 122
Shipbuilding Returns 125
Lady Williams Management and the Social Structure of the Firm 128
The Hirst Research Centre 131
Duke of Edinburgh to Deliver Graham Clark Lecture 135
Conference on Satellite Launcher Development 135
Hydrology of the River Severn . . . . Midland Motorway Links 135
Award of James Watt Medal . . . . Racing Tyre Recognised 135
Symposium on Industrial Vacuum Plant 135
Simulator for Nuclear Power Stations . . . . Fuel Dispensing System . . . 136
Rapid Reconstruction in a Steel Works 136
International Course in Hydraulic Engineering 136
Tractor-Mounted Sprayer . Gear Shaving Machine . Engine-Driven Cleaning Spray 137
Joints for Tubular Structures . Automatic Test Equipment . Cold Forging Press 138
Size Control Honing Tool . Harmonic Analyser . Universal Hardening Fixture 139
High-Pressure Solenoid Valve . *In Situ* Construction of Concrete Floor and Roof Slabs 140
Pivoted Disc Valves 140
Electro-Pneumatic Valve Positioner . . . Automatic Paint Spraying Machine . 141
Powder Welding Torch for Hardfacing 141
Dowel Inserting Press . . . Polishing Machine . . . Hydraulic Clamp . . 142
Lock Gate Power Operating Equipment . . . . Grinding Indicator 143
Continuous Weighfeeder for Process Materials 143

Continental Affairs

French "Bulb" Sets for Tidal and Low Head Power. No. I 146
Euratom Transuranes Centre 148
Automatic Indexing Machine 148
Esch-sur-Sûre Dam 148
Eastern European Pipeline 148
German Car Production 148

American Scene

The 1961 Cars 149
Production of Strip from Powder 150

LETTERS Floods. Millions to be Saved, with Improved Safety 126

BOOK REVIEWS 126

NEWS AND NOTES Industrial News 144
Personal and Business 145
British Patent Specifications 151
Catalogues and Brochures 152
Forthcoming Engagements 152

INDEX TO ADVERTISERS : PAGE 113 **CLASSIFIED ADVERTISEMENTS : PAGE 104**

NOTICE TO READERS No undertaking can be given to return illustrations or manuscripts Correspondents are requested to keep copies. No notice is taken of anonymous communications.

SUBSCRIPTIONS U.K. and ABROAD £5 10. 0. p.a., including postage (CANADA £5 5. 0.). Single copies 2s. each, plus 9d. postage. Also on sale at newsagents.

'THE ENGINEER' BUYERS GUIDE Published annually. One FREE copy is sent to all direct postal subscribers on publication and delivered by newsagents to all regular readers. Additional copies are obtainable at 10s. 0d. each. Postage 2s. 0d. extra.

Published every Friday by

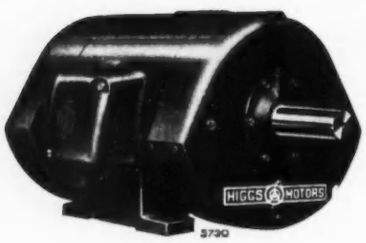
MORGAN BROTHERS (PUBLISHERS) LTD., AT 28, ESSEX STREET, STRAND, LONDON, W.C.2. Telephone : CENtral 6565

TRADE MARK

HIGGS MOTORS LTD.

MANAGING DIRECTOR DAVID C.Y. HIGGS. A.M.I.E.E.

BIRMINGHAM 6 ENGLAND



DRIP PROOF MOTORS

STANDARDISED DIMENSIONS
CLASS 'E' INSULATION
COMPLYING WITH B.S.2613

BELFAST · BRISTOL · CARDIFF · DUBLIN · DUNDEE · GLASGOW · HULL · LEEDS · LIVERPOOL LONDON
MANCHESTER NEWCASTLE · PETERBOROUGH · SHEFFIELD · WOLVERHAMPTON

Enter No. 21 on reply card

THE ENGINEER

No. 5479 JANUARY 27, 1961 Vol. 211

INTERNATIONAL ROCKETRY

Next Monday an international conference opens at Strasbourg. It has been convened by the British and French Governments to consider co-operation between European and Commonwealth countries on the development of a heavy satellite launcher. Fuller details are given on page 135. When in April of last year the decision was reached to abandon the development of the British "Blue Streak" rocket as a weapon of war we, amongst others, immediately offered the suggestion that, since there was no longer need to maintain secrecy about its design, an approach should be made to other European countries to see whether there could be international collaboration in space research, using "Blue Streak" to set satellites in orbit. We now hope the conference will prove successful.

Politicians, of course, are worried about the high cost of rocket research and some have stressed that this country cannot, alone, bear the cost. Many scientists, appreciating that point, and being dubious, also, about the likelihood that there will ever be any commercial return for the cost of such research, have welcomed the generous American plan for placing British satellites cheaply in orbit by American "Scout" rockets; but others are less happy about it as they would prefer Britain to have fuller control of the way its satellites are to be launched. Engineers, we think, are not happy at all about a programme which would debar them from gaining experience in the advanced techniques of rocketry; and commercial concerns, having in mind the possibility of transmitting information long distances more cheaply by utilising satellites as "repeaters" than by cables, and of improving radio techniques through improved knowledge about the ionosphere (see article "Commonwealth Communication" below) are bound to feel uneasy. Moreover, past experience suggests that commercial uses are eventually found for many discoveries in "pure" science; and in the engineering sense, techniques of design or production developed to meet such extreme service conditions as those encountered in rockets become applicable with advantage in other engineering fields.

Of course by American and, no doubt, Russian standards, "Blue Streak" is not an advanced design of rocket; and, having been designed to be a single stage missile, it is not as well adapted to be the first stage of a two-stage space rocket as a device designed from the first for that purpose. But the design exists. Construction is far advanced. Preparations have been already made at Woomera to test it. Within a short while a first firing could be made. Experience could thus soon be gained of firing and controlling a rocket of the large size needed for the setting of heavy satellites in orbit — experience which would be invaluable for the design of a second generation rocket better adapted to its purpose. Moreover well before the new generation rocket could reach the firing stage of development the combination of "Blue Streak" with a "Black Knight" or with a similar rocket of Continental design could have set satellites in orbit.

It can be agreed that the cost of rocket development to support a wholly British programme of space research would be too great for this country to bear. But we find it difficult to believe that engineers and scientists on the Continent of Europe are any less interested in space research — or in the commercial use of satellites — than their British counterparts. There are plenty of examples of fruitful co-operation internationally in the scientific and engineering research fields and we see no reason why there should not be fruitful co-operation in this one too. Nor do we think Europe and the Commonwealth must remain for very long far behind the Americans and Russians in their development of rocket technology. We have a lot of faith in the abilities of British, European and Commonwealth engineers. They would be working with single-minded devotion towards the development of rockets for space research and not for war. There would be the immense advantage that there would be little if any secrecy so that criticism and exchange of knowledge could beneficially influence the development of any project. The rate of advance might well prove high.

COMMONWEALTH COMMUNICATIONS

Only five years ago the Commonwealth Telecommunications Board proposed a cable route from Canada to Australia and New Zealand by way of the United Kingdom, Africa, India and Ceylon. At that time it did not appear technically practicable to provide such a cable from the Canadian western seaboard across the Pacific to Australasia. By the time the Commonwealth Telecommunications Conference met in 1958, however, sufficient scientific advance had been made, and technical experienced gained, for it to recommend a round-the-world cable system including a Pacific Ocean link joining Australia and New Zealand to Canada. The development

which made this possible was the lightweight submarine cable and rigid two-way repeater, enabling a single cable to carry traffic in both directions. This system was used in 1956 for the section of the Trans-Atlantic telephone cable (TAT) between Newfoundland and Nova Scotia, although the main Atlantic section was on the American system with two cables. The long-distance project using the new technique was the CANTAT cable between the United Kingdom and Canada, due for completion this year, this being the initial step in the round-the-world scheme. The next step is the Pacific crossing from Canada to Australia and New Zealand. Orders were announced this week for 8,700 nautical miles of similar cable and 335 rigid repeaters for this Trans-Pacific link. The orders were placed by the management committee of the project, comprising representatives of the Overseas Telecommunications Commission (Australia), Cable and Wireless, Ltd., the United Kingdom Post Office, the Canadian Overseas Telecommunication Corporation and the New Zealand Post Office. Two British firms are sharing in the manufacture of the cable and repeaters — Standard Telephones and Cables, Ltd. and Submarine Cables, Ltd. (owned jointly by Associated Electrical Industries, Ltd. and British Insulated Callender's Cables, Ltd.) Under the conditions of the contract as much of the raw material for the cable as possible is to be supplied from Australia and Canada.

When the decision was taken in 1956 to extend Communication services by means of cables, it was considered that no foreseeable development of radio techniques would be able to provide sufficiently stable multi-channel radio-telephone links of large enough capacity for the purposes in view. Already the outlook is changing with the advent of the communication satellite and its potentiality as a channel for high-capacity telephony and television systems in the frequency range between 1,000 and 10,000 Mc/s, which is free from the fading and disturbances to which the normal short-wave communication bands are liable. But forecasts are that satellite systems will not begin to supplement existing cable and radio services within another ten years. Thereafter the future is more uncertain. Studies of the ionosphere, for example, are being advanced by observations from new angles made possible by space vehicles. At the recent inspection of the new "Minitrack" station at Winkfield, representatives of the Radio Research Station at Slough made it clear that while extending their interests in space they are keeping their feet firmly on the ground in that their work is directed to improving communications. Even another five years might see a new assessment of the relative importance in the future of cable and radio links for Commonwealth communications.

PRESSURE VESSEL DESIGN

It rarely happens that a technical symposium sets out its terms of reference so specifically and concisely as was done in the recent meeting on pressure vessels organised by the Institution of Mechanical Engineers in conjunction with the British Welding Research Association. For what could be more explicit than the title "Pressure Vessel Research Towards Better Design"? Moreover the content of the papers discussed at the symposium fully justified the scope of the title. And yet an uninitiated observer attending the symposium would probably have sympathised with the sentiments of the delegate who commented on the proceedings by asking the leading question "where do we go from here?" How in fact, is it possible to correlate the diverse codes of practice recognised by the industry, with the mass of technical information that was disseminated and discussed at the meeting?

Generally, pressure vessel design is guided by a blend of theory and practical experience and is governed largely by the provisions of a number of accepted codes. Among these factors the influence of the codes is predominant, despite the apparent anomaly that, as detailed in Lancaster's paper (page 122 of this issue) there are prodigious differences in the scope and authority of the codes recognised in various countries. In some, for example India, the codes take the form of statutory regulations. In others, such as Germany, the codes are framed by independent bodies and authorised by the Government. At the other end of the scale Belgium and Israel achieve adequate standards of safety without codes or detailed government supervision. In fact, as Mr. Lancaster pointed out, the safety records of pressure vessels in the countries referred to in his paper depend as much upon sound design and the commercial integrity of the manufacturers as upon compliance with codes!

Nevertheless the codes, whether mandatory or not, provide (*inter alia*) a useful yardstick for comparing the accepted practice in the manufacture of pressure vessels in different countries. In Great Britain the existence of three recognised codes, partly overlapping in scope, offers a tempting target for criticism. Moreover, Great Britain and France are alone among the countries considered in that, although there are national codes, no single one is universally accepted nor is there any one code-administering body. Mr. Lancaster and other delegates at the meeting considered that Great Britain should have a single code for boilers and pressure vessels, with a single organisation to administer it, as a desirable step towards standardisation and economy in the industry. As might have been expected, other speakers strongly deprecated the concept of unification of the existing codes and of the administrative bodies. On the one hand it was asserted that these codes, despite their imperfections, had served the industry well. On the other it was suggested that it would be easier and quicker to promote technical advance by refinement of each separate code rather than by consolidation of all the codes. Perhaps the core of the matter is the need for an organisation that will codify practice without retarding technical progress and some interesting ideas towards this end were postulated in W. B. Carlson's paper, reproduced on page 125. Briefly the aims are to encourage a more rational design procedure based on idealised pressure vessel conditions; to intensify research on the real effects of departures from these conditions, in relation to practical modes of failure; and to ensure that codes should be promptly revised to exploit the results of authenticated research and experience. It is a major task: the first part is to counteract the tendency of rules and codes to become entrenched; the second is to ensure that there is sufficient technical effort and progress to justify refinements of the codes. A preliminary step is to set up a branch to interpret and assess the proceedings of the symposium and we are glad to note that the organising committee has this object in mind.

BRITISH SHIPPING AND FUTURE PROSPECTS

The General Council of British Shipping recently issued a document which was prepared by the policy committee of the Industry. It surveys the present state and future prospects of British shipping and includes

policy recommendations. It is recalled that in the forty years ended 1910 the British foreign trade and merchant fleet increased by 100 per cent and that at that date roughly 50 per cent of world trade was carried in British ships, which also represented about half of the world's tonnage. But two world wars resulted in losses amounting to 18,000,000 tons, while the size of the fleet, which remained practically static between the wars, fell to 26 per cent of the world total in 1939 from 40 per cent in 1914 and by 1959 to 17 per cent, despite additions to the fleet. Depressed trading conditions in the inter-war years resulted in the passing of the British Shipping (Assistance) Act in 1935 to help tramp shipping. It is emphasised in the Survey that by contrast, in the post second world war period, seaborne dry cargo increased, by 1958, to 63 per cent over that carried in 1950 and the corresponding figure for tankers was as much as 96 per cent. Despite expanding trade, however, laid up shipping reached a peak of 8,900,000 tons in 1959; and last year it was about 4,700,000 tons, not a surprising figure when it is recalled that the world fleet increased by 24,000,000 tons in the four years 1954 to 1958. The Survey points out that many forces are now operating to modify the law of supply and demand; and that many obstacles prevent free access to world markets. Nationalists flag fleets mean a reduction in the United Kingdom's share of trade since they contract the competitive field and this form of competition cannot be met by the offer of cheaper or more efficient services.

The Survey next points out that 99 per cent of all this country's trade is seaborne of which British ships carry 51·1 per cent of the imports and 61·4 per cent of the exports. For 1952 the value of these services is given as £754 million gross in foreign trade and as a contribution of £221 million to the balance of payments, but the latter figure fell to £100 million in 1959. Direct employment in the industry is stated to be 140,000. British shipyards have benefited since the war by orders for about 15,000,000 tons of shipping valued at £1,600 million. Further figures given for 1959 indicated the value of British shipping to British shipbuilding, because 1,100,000 tons, out of a total output of 1,400,000, was for British owners. It is pointed out that the continued existence of our merchant fleet depends on commercial considerations. If it is no longer found possible to compete on a commercial basis for international trade there must necessarily be a gradual reduction in our merchant fleet — unless, of course, aid of some kind is forthcoming. The Survey, which covers all sections of the industry from deep sea liners to whalers, reveals that all are now affected by increasing competition and that all were handicapped immediately after the war by having to replace crippling war losses in spite of the fact that insurance compensation consequent upon inflation proved very inadequate. Governmental action in relation to shipping and departmental administration is examined and so are the various forms of flag discrimination. Other difficulties with which British shipowners have to combat are studied in the Survey. It discusses, for example, direct and indirect subsidies, flags of convenience, and taxation. Against flag discrimination countermeasures are considered essential if persuasion fails to prevent the practice: it is urged that the Government should obtain general powers to apply such measures and also that strong anti-discrimination clauses should be embodied in commercial treaties. As for subsidies, the Survey suggests that financial aid should be made available to any British shipping service the continued existence of which is threatened by subsidised competition, including the competition offered by subsidised air transport to passenger liners and by subsidised railways to the coasting trade. Additional taxation relief or permission for British owners to take advantage of low taxation elsewhere is proposed to offset the advantages of flags of convenience.

The Survey gives factual support to the warnings which owners of various classes of tonnage have voiced in recent years. It brings out the contraction of the British share of world shipping since the war and clearly illustrates in terms of hard cash the diminishing contribution of British shipping to the balance of payments. The factors largely responsible for the present position, such as flag discrimination, subsidies, flags of convenience and taxation at home are also emphasised. It is argued, reasonably enough, that commercial skill and operational efficiency cannot succeed in the face of government regulations abroad and other devices adopted by other nations designed to exclude the shipping of all but their own nationals. The General Council clearly feels that if protests fail to persuade other countries to give up the use of artificial aids then it rests firmly with the Government to adopt suitable counter-measures, keeping in mind that shipping is still the lifeline of the country. It is hard to disagree, even though the fear must be expressed that once this country discriminates in favour of its nationals world-wide discrimination will become far worse than it is at present. Is the industry sure that it would benefit?

The Engineer—100 Years Ago (JANUARY 25, 1861)

"DESCRIPTION OF AERTS' WATER AXLE-BOX"

"The attention of engineers and carriage builders has been constantly directed to improvements in railway axle-boxes, as shown by the various contrivances that have been invented for the purpose. These, however, have all included the use of oleaginous matter as a lubricator, though it is well known that there is an inherent defect attached to such a material, since the brass bearing must be heated by the friction of the journal before the grease can be brought down to lubricate the bearing. If a perfect lubricator for railway axles could be obtained, it would effect a great saving both of tractive power and also of commercial cost, as compared with a material which performs its duty in an imperfect manner. The essential conditions of a good method of lubrication are—first, there should be a constant and abundant supply of a pure lubricating fluid; and, secondly, the working parts should be always kept free from foreign substances, the tendency of which is to increase the friction or to intercept the free contact of the lubricating material with the bearing surfaces. These conditions are successfully fulfilled in the simple construction of axle-box now about to be described; the principal feature of which is the use of water as the lubricator, in place of oil or grease which has generally been used on railways, thus avoiding the many inconveniences that have resulted from the use of fatty substances.

"The water axle-box is the invention of M. Aerts, of Belgium . . . On the end of the axle a cast-iron disc is firmly fixed, working in a reservoir of water. When the carriage moves, the disc turning round with the axle raises the water by the centrifugal force of its rotation into the upper part of the axle-box, where it is caught by the brass scraper resting loosely on the top of the disc, and is discharged into the inclined spout, which conducts it directly over the axle, and thus lubricates the bearing completely and continuously."

Consett Plate Mill

There is still a growing demand from a great variety of industries for steel plate. In all its applications steel plate is currently required to meet increasingly strict specifications, both metallurgically and in dimensional tolerances. A modern plate mill has to be designed not only for economic production of large tonnages, but also to handle a range of specifications and work to a degree of accuracy unheard of even a few years ago. The latest plate mill to be commissioned, at the works of Consett Iron Company, Ltd., Consett, County Durham, is designed to roll plate in large tonnages and is equipped with ancillary plant to carry out a number of finishing operations as well.

CONSETT IRON COMPANY, LIMITED, has been a leading producer of steel plate for many years, and a new plate mill featured prominently in the company's development plan which is now in hand. Before deciding what type and size of mill to instal, Consett carried out an extensive market survey. This showed that the development would be best carried out in two stages. The first of these, which is now complete, comprises a 132in four-high plate mill, together with a very wide range of ancillary and finishing equipment. Provision is made in the layout for the addition of a second mill, capable of rolling plate up to 160in wide, at a later date.

The new plant, known as Hownsgill Mill, is built on a new site near to the existing steel works. It is designed to produce initially 8000 to 10,000 tons a week of steel plate up to 125in wide (120in sheared width) in lengths up to 90ft and from $\frac{3}{16}$in to 4in thick. Plates of these dimensions will be produced from slabs measuring from 36in to 60in wide, from 54in to 120in long, up to 20in thick, and up to 25,000 lb maximum weight.

Slab Heating

As the range of slab sizes is large, it was decided to install two different types of furnace for slab heating. Continuous "Rust" triple-fired pusher furnaces deal with the bulk of the production, and the remaining slabs, which are either too thick for the continuous pusher furnaces, or too short to ride the skids when pushed, are heated in soaking pits of special design. There are at present two continuous furnaces and two soaking pits ; space has been left for a third continuous furnace to be installed later. Both the continuous furnaces and the soaking pits were designed and constructed by Stein and Atkinson, Ltd., Kew Road, Richmond, Surrey.

Each of the continuous furnaces has an effective heating length of 85ft and is 23ft wide inside the walls. Each furnace is designed to heat 100 tons per hour of slabs 9ft long by 10in thick from cold to rolling temperature, the slabs being charged in two rows. Slabs from 5ft 6in to 10ft long, and occasionally of a maximum thickness of 15in, can also be heated ; the 15in thick slabs are, however, limited to 8ft 6in in length. The furnaces are fired with heavy fuel oil delivered from a storage, pumping and heating station near the end of the mill building.

The furnaces are end charged, slabs being brought to the charging end on a roller table, lined up with the slabs already in the furnace, and pushed in by electrically operated pushers ; there is one pusher for each of the two rows of slabs. Firing is by "Rust" back-atomised burners, the oil being atomised by steam and burned with preheated air from Newton needle recuperators alongside each furnace. There are three firing zones—heating above and below the slabs, and soaking, with independent oil/air ratio control for each zone and linked temperature control for the upper and lower zones, the upper exercising the control. The soaking burners are controlled in a single zone. All the control equipment is housed in a glass-fronted instrument room adjacent to the furnaces.

Combustion air is supplied by a Davidson fan of 37,500 cubic feet per minute capacity and passed through the recuperators, which are designed to give an air preheat of 450 deg. Cent. with products of combustion entering at 900 deg. Cent. Waste gases are drawn through the recuperators by Davidson fans—one for each furnace—of 100,000 cubic feet per minute each at 450 deg. Cent. A chimney 80ft high and 6ft diameter inside the lining is provided for each furnace.

For the slabs not dealt with by the pusher furnaces there are two "Elpit" electric soaking pits which can also be fired with heavy fuel oil. These pits are designed to take slabs from 5ft to 10ft long, up to 20in thick, and with a maximum width of 5ft 6in. Each of the pits has one row of four cells, the individual cells being 8ft long by 5ft 6in wide by 11ft deep, and capable of holding two of the maximum-sized slabs. Together the "Elpits" are capable of heating 2500 to over 3000 tons of slabs per week. Each pit has a resistor at each side fed with current from a 750kVA single-phase transformer ; these resistors are essentially coke-filled troughs, which transmit heat to the slabs mainly by radiation, and give very uniform heating. Lift-off covers and a rail-mounted cover lifting machine are provided on each pit.

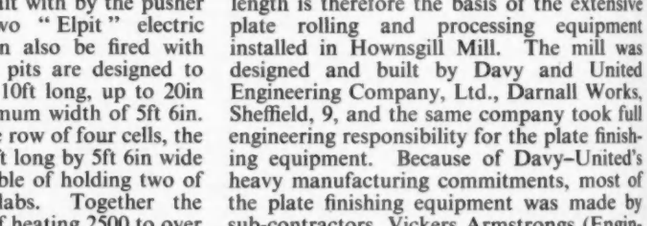
In addition to the electric heating resistors the pits are each equipped with eight oil burners of the Schieldrop self-proportioning type. The method of operating the pits is to fire them with oil until the slabs have reached 900 deg. to 950 deg. Cent., or some other preset temperature, when the heating is automatically changed over to electric, the resistors having been brought up to working heat before the oil is turned off. The automatic changeover is sequential and interlocked, and provides audible warning if conditions should change in such a way as to require the attention of an operator.

Hot Rolling

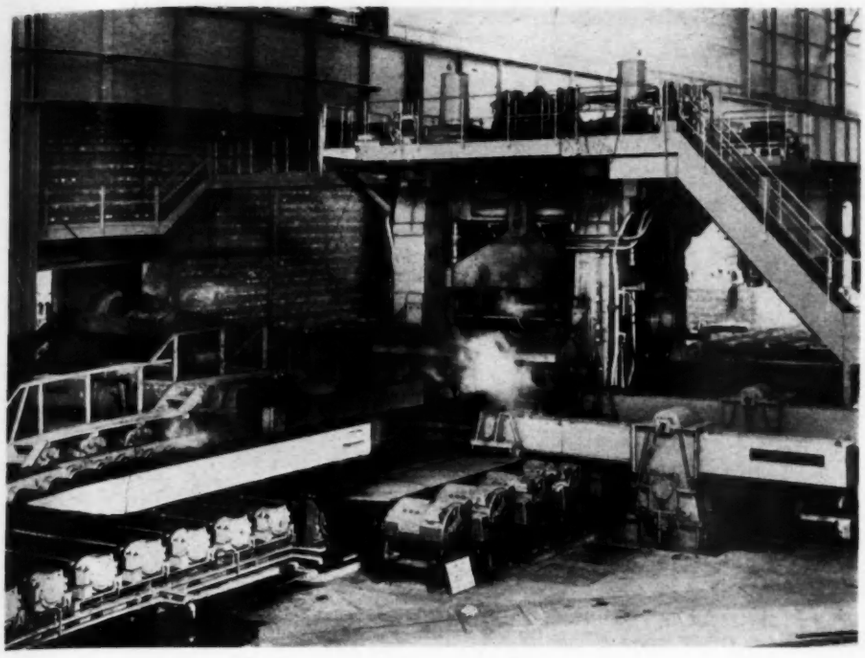
As already mentioned, customers' requirements for steel plates are exacting, and it is for this reason that the four-high mill, established for many years for rolling thinner products, is now becoming the standard for the heavier flat products. A four-high mill, in which the work rolls are relatively small and are supported by heavy back-up rolls, has several advantages. Because the work rolls are small, heavier reductions in product thickness per pass are possible. This speeds up the rolling procedure, and makes higher output possible. Faster rolling speed is also of importance when alloy steel is being rolled ; rolling temperatures are then critical, and it is vital that the mill should complete its work on a plate while temperature is within a limited range. There is also the advantage that the design of a modern four-high mill lends itself to the incorporation of the stiffness feature which is essential if present-day dimensional accuracy specifications are to be met.

A four-high reversing hot mill with work rolls 39in diameter by 132in barrel length and back-up rolls 60in diameter by 132in barrel length is therefore the basis of the extensive plate rolling and processing equipment installed in Hownsgill Mill. The mill was designed and built by Davy and United Engineering Company, Ltd., Darnall Works, Sheffield, 9, and the same company took full engineering responsibility for the plate finishing equipment. Because of Davy-United's heavy manufacturing commitments, most of the plate finishing equipment was made by sub-contractors, Vickers Armstrongs (Engineers), Ltd., Elswick, Newcastle upon Tyne, and The Brightside Foundry and Engineering Company, Ltd., Ecclesfield. The consulting engineers for the whole Hownsgill project were the International Construction Company, Ltd., Kingsway, London, W.C.2.

On leaving the slab heating furnace, slabs pass into a descaling station, where high-pressure water sprays, three located above



A slab is discharged from the reheating furnace and passes through the descaling station



Four-high hot plate mill

and one below the slab, remove scale before the slab enters the mill. Two of these sprays are in operation at any one time ; the one below and one of the three above. These top sprays are arranged at different heights, and the appropriate one operates according to the slab thickness. Each of the spray headers has eleven nozzles, which direct water at 1500 lb per square inch on to the slab surface ; this gives a minimum impact force of 10 lb per inch of slab. The descaled slab passes to a delivery table and thence to a rope-hauled transfer buggy which takes it across a 141ft gap in the roller table line to the ingoing extension table of the 132in mill. This gap is left in the mill line to allow for the installation, at a later date, of the previously-mentioned 160in rolling mill.

From the extension table the slab passes to the main ingoing table of the 132in mill. This table and the corresponding outgoing table are equipped with fifteen individually-driven solid-forged steel rollers mounted in SKF self-aligning roller bearings. Broadsiding of slabs is effected by reversing the roller drive motors on one side of the table or the other. Both ingoing and outgoing tables are equipped with adjustable side-guards.

An important feature of the 132in mill is its massive construction. Each of the two mill housings is a single-piece steel casting, with a finished machined weight of approximately 156 tons, and having post areas of about 1100 square inches. These housings not only have to carry the roll and chock assemblies, which total over 300 tons, but have to withstand the roll-separating forces produced in rolling, estimated to be about 3000 tons. To give some idea of the precision requirements in the machining operations, it can be noted that the housing window, which is 5ft 9in wide, is machined to an accuracy of ±0·002in over a length of 20ft.

The mill is arranged for a twin motor drive from two 5180 h.p. 45/80 r.p.m. motors, through universal spindles and couplings, to give a mill speed range of 460ft to 816ft per minute. Both top and bottom spindles are hydraulically balanced at the mill end, and spring balanced at the motor end. The jaw ends of the spindles and the motor end couplings are all mounted by the oil injection method. Timken roller bearings carry the 39in diameter work rolls and " Morgoil " bearings are used for the 60in back-up rolls ; these back-up rolls weigh over 60 tons each. Both back-up and work roll assemblies are hydraulically balanced, and both assemblies can be changed simultaneously by means of an electrically-driven rack-type rig.

Twin motor screwdown gear with a magnetic clutch for separate screw adjustment, and driven by two 200/520 h.p., 420/1000 r.p.m. motors, gives screwing speeds between 30in and 72in per minute. Limit switchgear prevents over-running of the screws, and the screwdown position is indicated in the control pulpit by means of " Selsyn " equipment ; there is also a mechanical dial indicator on the mill itself. Semi-automatic positioning control is provided, allowing the mill operator to preset the screws. Provision is also made for separating the rolls should they accidentally become jammed, either in contact with the steel being rolled, or with each other.

Feed rollers 20in in diameter and 112in long on the barrel are provided at both the entry and delivery sides of the mill, to facilitate the entry of the slab or plate at each pass. There is also a high-pressure descaling system on the mill itself ; this is supplementary to the descaling station at the furnace exit.

Plate Finishing

The bulk of the plate rolled by the mill is in the range $\frac{5}{16}$in to 1½in, and there are two independent shearing lines, the lighter line handling the plate from $\frac{5}{16}$in to ¾in and the heavier one dealing with plate up to 1½in thick. Plate between 1½in and 4in thick, which can also be rolled, is flame-cut to the required size.

Plate up to 1½in thick is sent straight from the mill to a 138in wide, nine-roll back-up leveller which can operate at 100ft per minute on plate up to ¾in thick and 50ft per minute up to 1½in thick. Levelled plates are then transferred to a cooling bed of the machined cast iron grid type, which minimises distortion of the plate while it is cooling. At the far end of this bed the plates are turned automatically for inspection and pass off the cooling bed to the first cross-cut shear, where they are cut to marked sizes. Marking is carried out on a motorised machine travelling on a rail track alongside the marking table at varying speeds up to 5ft per second. Three cross-travel magnets enable the plates to be aligned for marking.

This first cross-cut shear and the two similar shears in the light and heavy plate finishing lines are all of the " rocking blade " type, designed by Moeller and Neumann G.m.b.H., of Saint Ingbert, Saar, Germany, and built by Davy–United under an exclusive manufacturing agreement for Great Britain. A shear of this type is essentially a down-cutting shear with a rocking arm action to the top blade. When the shear is at rest the top and bottom blades are parallel. During the cutting operation one side of the top blade is lowered, while the other side is lifted slightly for an instant, the motion being effected by staggered eccentrics. This shearing action results in cleaner edges, less bow in the plate after shearing, better shaped plates, cleaner scrap, and decreased strain hardening in the body of the plate.

After shearing the plates are discharged to one of two transfers, each of which is 60ft

Automatic turn-over gear for plate inspection in the finishing line

wide and operates at 100ft per minute. Scrap from the shearing operation on this shear, as on the other shears in the mill, is cut up automatically. Plates carried across the transfers are routed either to the heavy or the light shearing line.

The heavy line is reached via a 60ft transfer bank and an approach table leading to the first of two side-trimming shears ; both are of the rocking blade type. The right-hand edge of the plate is trimmed on the first shear, and the left-hand edge is cut on the second shear, 94ft further down the line. A motor-driven adjustable straight-edge facilitates shearing to predetermined width, and four cross-travelling magnets ensure accurate alignment at the second shear. Trimmed plates run forward for final cutting to length on a cross-cut shear, which is complete with adjustable straight-edge and cross magnets. Finally, the finish-sheared plates are transferred to a 60ft wide bank and thence to a run-out table, from which they are lifted by semi-Goliath cranes and piled in stacking areas.

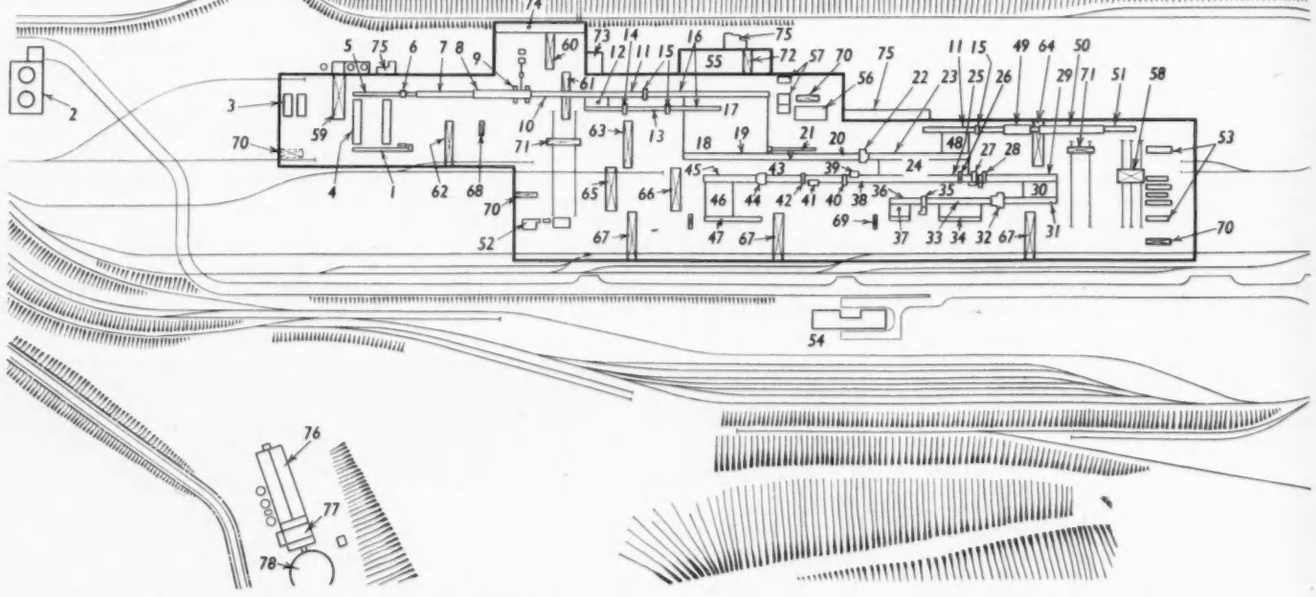
One of the side-cut shears in the finishing line

Light Shearing

Plates for the light-shearing line are discharged from the transfer to a runout table and then to the approach table of a rotary side trimming shear. This approach table is equipped with three magnets for cross travel and one for longitudinal travel, to enable the plate to be positioned before shearing. The rotary side trimming shear itself shears both edges of the plate simultaneously and can cut plate up to ¾in thick. It employs two pairs of forged alloy steel circular cutters, the top ones being 15in diameter and those at the bottom 60in diameter. A rotary scrap shear, scrap elevator and chute dispose of the shearings. On the outgoing side a rotary slitting shear cuts the plate to specified widths.

A 60ft wide transfer bank is next in line, and plates from this bank are delivered to a rocking blade cross-cut shear, capable of cutting plates up to 120in wide. A scrap shear is incorporated. After shearing at this point plates can be removed from the line by means of another 60ft wide transfer bank.

A feature of the light shearing line, however, is the facility for cold levelling. Plates



1—Slab furnace de-piler pushers and charging tables.
2—Oil storage.
3—Oil electric soaking pits.
4—Slab reheating furnaces.
5—Furnace delivery tables.
6—Descaling station.
7—Transfer bogie.
8—Mill approach tables.
9—132in mill.
10—Mill delivery tables.
11—Hot leveller approach table.
12—Chequer mill transfer bank.
13—Chequer mill run out tables.
14—Chequer mill.
15—Hot levellers.
16—Hot levellers run out tables.
17—No. 1 and 2 cooling banks.
18—No. 1 and 2 plate turnover gear.
19—Cooling bank delivery table.
20—Marking table.
21—Marking machine.
22—40mm cross cut shear.
23—Shear run out table.
24—Transfer bank.
25—Transfer bank delivery tables.
26—¼in rotary side trimmer.
27—Scrap disposal.
28—Slitter.
29—Slitter run out table.
30—Transfer bank.
31—20mm cross cut shear approach.
32—20mm cross cut shear.
33—Shear delivery and cold leveller approach.
34—60ft transfer bank.
35—Cold leveller.
36—Cold leveller run out table.
37—40ft transfer bank.
38—Heavy shear line transfer bank run out table.
39—No. 1 40mm side cut shear.
40—No. 1 scrap shear and disposal.
41—No. 2 40mm side cut shear.
42—No. 2 scrap shear and disposal.
43—Heavy cross cut shear table.
44—Heavy cross cut shear.
45—Heavy cross cut shear run out table.
46—60ft heavy shear line transfer.
47—Transfer bank run out table.
48—Hot leveller transfer bank.
49—Pressure quench.
50—Normalising furnace.
51—Normalising furnace approach table.
52—Shot blast plant.
53—Reheating furnaces and cooling beds.
54—Amenities block.
55—Electrical and mechanical shops and offices.
56—Roll grinding facilities and equipment.
57—Roll storage.
58—Furnace charger.
59—25-ton charger.
60—75/5-ton motor room crane.
61—150/30-ton mill bay crane.
62—40-ton marking bay crane.
63—30-ton marking bay crane.
64—15-ton marking bay crane.
65—10-ton shear bay crane.
66—15-ton shear bay crane.
67—15-ton loading bay cranes.
68—20-ton semi-Goliath cranes.
69—5-ton semi-Goliath cranes.
70—10-ton maintenance cranes.
71—Transfer bogies.
72—7½-ton shop crane.
73—Air compressor house.
74—Transformer bay.
75—Substations.
76—Settling ponds.
77—Pump-house.
78—Cooling tower.

Diagrammatic layout of mill, finishing lines and auxiliaries

requiring this treatment are not discharged by the transfer bank, but travel straight forward to a 9in by 9in by 138in backed-up type cold plate leveller. This eleven-roll machine will level, in one pass, cold plates from approximately $\frac{3}{16}$in to $\frac{1}{2}$in thick. Cold levelled plates are side transferred on to a 40ft wide transfer bank which will operate at the same speed as the cold leveller—100ft per minute. This is the end of the plate finishing line, and plates are removed, stacked and prepared for dispatch.

A certain amount of plate up to 1in thick is required finished in chequer pattern. Plate thus required is transferred from the 132in mill, across a 50ft wide bank and fed to a 24in and 42in by 84in, four-high chequer plate mill ; this mill has been converted by Davy–United from existing equipment. It is designed to produce diamond, dimple or Admiralty chequer plate up to 1in thick and 45ft long at speeds up to 350ft per minute. A 9ft 6in hot leveller, taken from existing equipment, is installed beyond the chequer plate mill. After this point the plate rejoins the main finishing line.

"Minitrack" Station at Winkfield

Winkfield, near Ascot, Berks., is the site of one of four new "Minitrack" stations which are being set up to extend the satellite tracking facilities provided by the existing ten stations of this kind, located mainly in North and South America. The installation provides tracking and telemetry facilities in the 136-137 *Mc/s band, and is operated by staff of the Radio Research Station of the D.S.I.R.*

THE "Minitrack" installation at Winkfield is ready to come into full operational use when satellites transmitting on 136-137 Mc/s are launched this year. With similar new stations in Minnesota, Alaska and Newfoundland, it provides cover on satellites having orbits with higher inclination angles than could be tracked by the earlier chain of ten stations in low latitudes which has existed since the beginning of the International Geophysical Year. Winkfield has outstations in the Falkland Islands and at Singapore which will enable the Radio Research Station to collaborate with American and Canadian scientists in the collection of data telemetred from apparatus flown in two satellites for investigating the upper portion of the ionosphere.

The equipment at Winkfield has been supplied on loan by the National Aeronautics and Space Administration. Tracking is by the interferometer method. The phase difference between signals received from a satellite on aerials spaced apart at accurately known positions is measured. By making simultaneous measurements between aerials set up on a North-South line and on an East-West line, the phase difference can be converted to give the angle in space of the satellite. Highest accuracy of angular measurement is given for a satellite immediately above the system, and in practice is likely to be of the order of a minute of arc, corresponding to a movement of only a few hundred yards for a satellite at a height of, say, 400 miles.

All the site preparation and erection at Winkfield was carried out by the Ministry of Works. The Ordnance Survey furnished a precise geographical location and was responsible for the accurate placing of the aerials. Base lines are accurate to five seconds of arc, and distances from the centre of the system are to an accuracy of $\frac{1}{8}$in. Calibration was carried out by the Royal Aircraft Establishment.

Tracking Installation

There are two separate interferometers. One (called the equatorial system) responds to signals arriving from a few degrees on either side of a vertical plane lying in the north-south direction and the other (the polar system) to signals arriving from a corresponding zone on either side of an east-west vertical plane. Either aerial system can be connected to the receiver. For each interferometer the component aerials (Fig. 1) are accurately placed at the corners of a square whose diagonals are some fifty wavelengths long and are directed along the N-S and E-W directions. These aerials are called the "fine" aerials since the phase difference between them varies rapidly with satellite direction and provides a correspondingly high acuity in directional observations. They are identical in construction, each comprising eight horizontal colinear elements connected in phase with a tapered amplitude distribution. The arrays are mounted above horizontal ground screens each 50ft by 25ft in size and all arrays are in the same horizontal plane.

The aerial arrays constituting the fine aerials of the equatorial system are arranged with the line of the component elements in the E-W direction and those for the polar system lie in the N-S direction. Thus each array has a vertically-directed fan beam with a width between 3 dB points of 11 deg. in the *H* plane and 76 deg. in the *E* plane. The pick-up polar diagram of each interferometer as a whole also has these characteristics since the fine aerials are all identical.

It is necessary to have auxiliary aerials called "ambiguity aerials" for measuring the integral number of 360 deg. involved in the phase difference between the fine aerials since the phase measuring equipment connected to these provides only the accurate value of the fractional part of 360 deg. Considering, for example, a satellite crossing the N-S fan beam provided by the equatorial system, if its angle of elevation is 45 deg., then the phase difference between the corresponding N and S fine aerials includes about 35 deg. by 360 deg. since the path difference between the rays reaching these aerials is about thirty-five wavelengths. This difficulty is overcome by means of the five ambiguity aerials which are arranged at much closer spacings. The ambiguity aerials each consist of a single horizontal element mounted above an 18ft square ground screen and have a vertically-directed pick-up polar diagram about 95 deg. wide in both *E* and *H* planes.

All aerials are connected to the receivers by buried low-loss aluminium sheathed coaxial cable which is pressurised with dry nitrogen in order to achieve stable transmission characteristics. Assuming that the direction of a satellite is such that the polar system has been selected, then the following aerials are connected through to the receiver : North polar fine, South polar fine, East polar fine, West polar fine, and all five ambiguity aerials. To enable the direction of the satellite to be determined, the following six phase differences have to be measured : N-S fine, E-W fine, N-S medium, N-S coarse, E-W medium and E-W coarse. The receiver has thus to be provided with six channels, which work simultaneously. Fig. 2 is a general view of the receiving equipment for tracking . The receiver can be spot-tuned to any one of 1000 frequencies between 136 and 137 Mc/s, the one selected being shown digitally above the three selector knobs at the lower left-hand corner of the console. The necessary beat frequencies are obtained by multiplication and division of fundamental crystal frequencies.

The process of N-S fine determination is typical of all those enumerated above. Signals from the N and S fine serials pass through separate preamplifiers and are then converted by frequency-changers to intermediate frequencies differing from each other by precisely 100 c/s (for identification purposes). The beating oscillators are crystal-controlled and the 100 c/s frequency difference required for the frequency conversion is phase-locked to a standard 100 c/s voltage obtained from a precision 1 Mc/s oscillator. Thus the original phase-difference between the N and S fine signal-frequency input voltages is represented by the phase of the 100 c/s beat note at the output of the receiver channel relative to that of the 100 c/s reference frequency. This phase difference is presented in two ways, as a d.c. analogue voltage and in digital form. In the latter case the two 100 c/s voltages operate a gate system which counts the number of cycles of 100 kc/s which fit in the time interval between

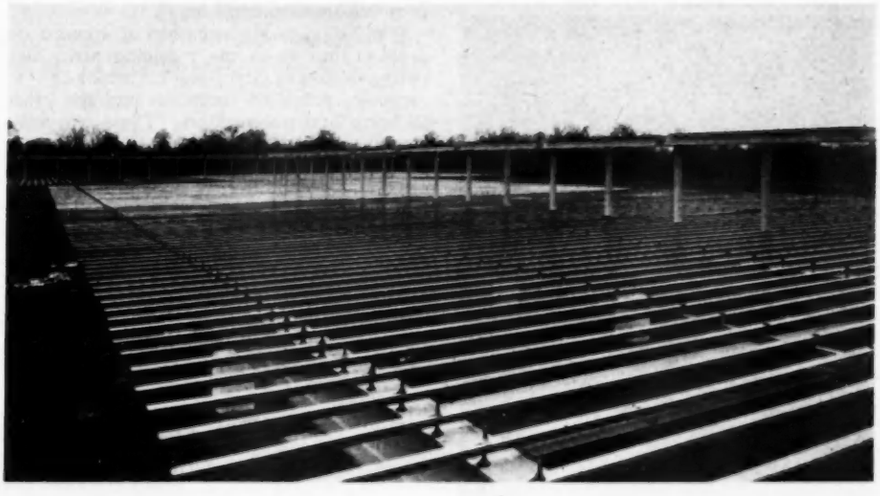


Fig. 1—Interferometer aerials and ground screens, showing elements of the equatorial and polar systems

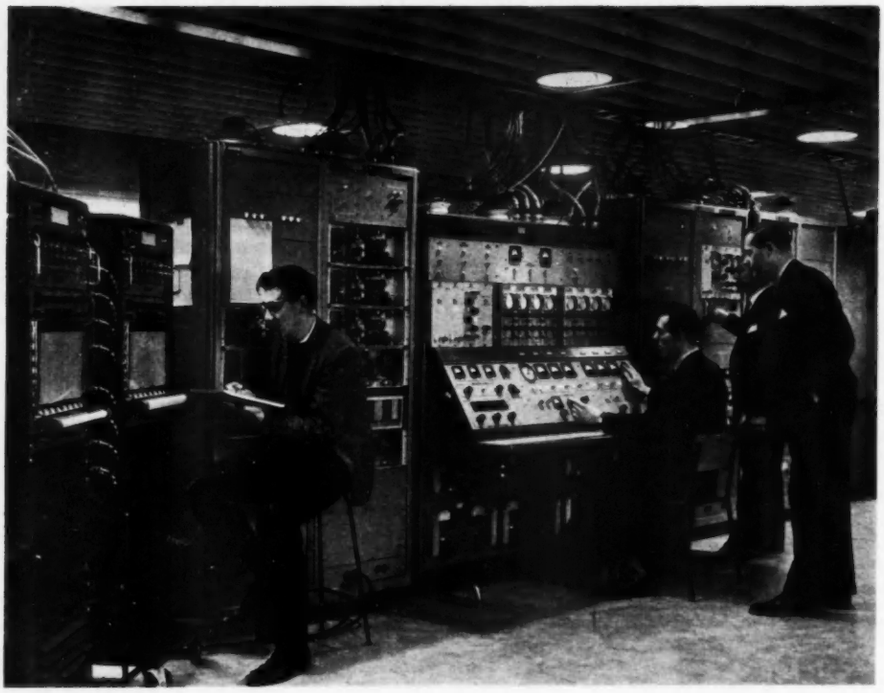


Fig. 2—" Minitrack " receiver (centre console), with phase recorders and measuring gear on left, standard frequency/timing rack to right of console and telemetry receiver on extreme right

corresponding points in the two 100 c/s waveforms. Thus each 360 deg. of 100 c/s phase difference (and therefore of the signal frequency phase difference) is split into 1000 parts and the digital display therefore has a phase discrimination of 0·36 deg.

The analogue and digital voltages (the latter in the form of a decimal code, read out five times a second) are applied to separate

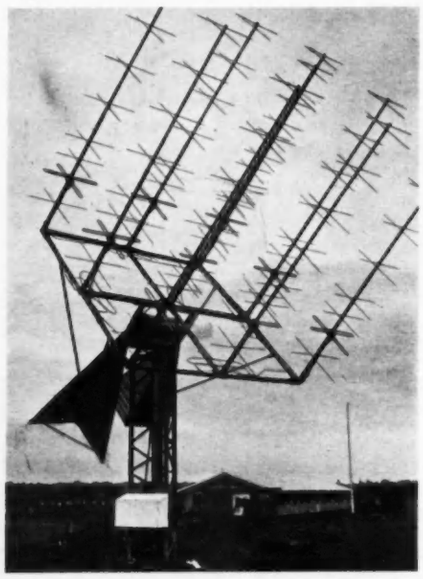


Fig. 3—Steerable telemetry aerial

pen recorders, a separate stylus being used for each of the six receiver channels (that is, aerial combinations). Additional channels on the recorders are used for indicating time and to record the signal strength.

Telemetry Installation

The final 136-137 Mc/s receiving system for telemetry has not yet been installed, but experience has been gained using signals on 108 Mc/s from " Explorer 8 " (launched on November 3). The 20 deg. beam aerial (Fig. 3) consists of an arrangement of nine Yagi aerials in a 3 by 3 array ; eight are used for reception, and the centre one is connected to a normal commercial v.h.f. transmitter which is available when required for altering the operation of the satellite (for example, to cause it to transmit any recorded experimental data).

Each Yagi is an assembly of crossed dipoles ; thus from the receiving array two voltages are available, one corresponding to vertically polarised reception and the other to horizontal polarisation. These two voltages are applied to low-noise pre-amplifiers at the base of the aerial system and the outputs are connected by buried feeders to the main building. Here plugboard connections are provided which permit the use of either of the two linear polarisations or the combination of the two voltages in phase quadrature so as to provide the equivalent of a circularly polarised receiving array. The single output from the combining unit is connected to the receiver input terminals. The whole aerial array can be oriented in any desired direction by remote control from the main building. At the moment the aerial system does not automatically follow a satellite once signals have been picked up.

Telemetry information is recorded on an eight-channel tape recorder. Satellite signals take various forms, but in a typical one the information is conveyed by the frequency of the oscillations in the pulses, the pulse width, and the pulse recurrence frequency.

A continuous teleprinter circuit is provided between Winkfield and the Goddard Space Flight Centre, and another leg of this is connected in parallel to the Radio Research Station at Slough. The main functions of these links are to provide predictions of forthcoming passes of satellites within the range of the station, and to transmit interferometer measurements and telemetry data in the reverse direction.

Calibration Checks

To check the overall behaviour of the polar and equatorial interferometers as direction finders it is necessary to calibrate them from time to time. This is done by means of a high-flying aircraft carrying a lamp which is switched on at known times, and photographing the track of the light against the star background which is used as a reference. At the instant the lamp is flashed on, the digital phase meter channels are recorded for the signal arriving from an extremely low power c.w. transmitter carried in the aircraft. The camera used (Fig. 4) is permanently mounted at the centre of the system ; it has a focal length of 40in and is mounted on a polar axis and driven so that star images remain stationary on the plate. The lamp on the aircraft is mounted at the centre of a downward pointing circularly polarised aerial which is fed by the aircraft transmitter operating on a frequency in the band 136-137 Mc/s. The aircraft also carries a receiver which picks up coded timing signals from a ground transmitter for flashing on the aircraft lamp ; these signals are the same as those which are used for time-marking the interferometer records. Thus the photographic plate provides, via the trace of the flashing lamp and the star background, the angular position of the aircraft relative to the centre of the interferometer system ; while the interferometer records provide the corresponding angular information for the radio system at the same instants of time.

Fig. 4—Camera and associated equipment for calibrating the " Minitrack " interferometer system

THE ENGINEER

Technical Contributors Section

JANUARY, 1961

Centrifugal Stresses at the Bores of Wheels

By H. FESSLER, M.Sc., Ph.D., A.M.I.Mech.E.,* E. I. HAY, B.Sc., Grad. R.Ae.S.,* and E. A. ROBERTS, B.Sc., Grad. I.Mech.E.*

The frozen stress photo-elastic technique was used to determine the centrifugal stresses at the bores of models of two types of wheels. The first type consisted of a thin flat plate web connected centrally to a cylindrical hub. Large axial compressive stresses were found in the bore near the plane of symmetry, where the greatest hoop stresses occurred. The maximum shear stress at the bore therefore greatly exceeded the value which would be calculated by the usual methods. Keyway stresses were also investigated. The second type had a hyperbolic profile which terminated at the full width of the hub. Some axial compressive stresses also occurred in this type of wheel.

CENTRIFUGAL stresses in turbine discs have been calculated for many years by generally accepted methods. Solutions for radial and hoop stresses are obtained by dividing the disc into a number of annular rings of rectangular or hyperbolic section and equating the radial stresses and displacements of these elements at their interfaces. These methods give two-dimensional solutions because variations of the hoop and radial stresses in the axial direction are neglected and axial stresses and shear stresses on planes containing the axis of the disc are ignored.

Various photo-elastic tests carried out at different times have revealed appreciable axial stresses at the bores of these rotating components. The purpose of this article is to draw attention to these stresses.

* Department of Mechanical Engineering, University of Nottingham.

Shapes of Wheels

Two shapes of wheel were used in this investigation. In the first type there was an abrupt change in thickness from a flat plate to a fairly wide hub, whilst in the second type the thickness changed gradually.

Three models of the first type of wheel were used. These were designed to the shape of typical gear wheels, but no teeth were cut. Their general shape is shown in Fig. 1. Model 1 has a plain bore ; model 2 had one keyway cut in the hub of the size shown ; model 3 had two diametrically opposite keyways of the same size, but a shorter boss.

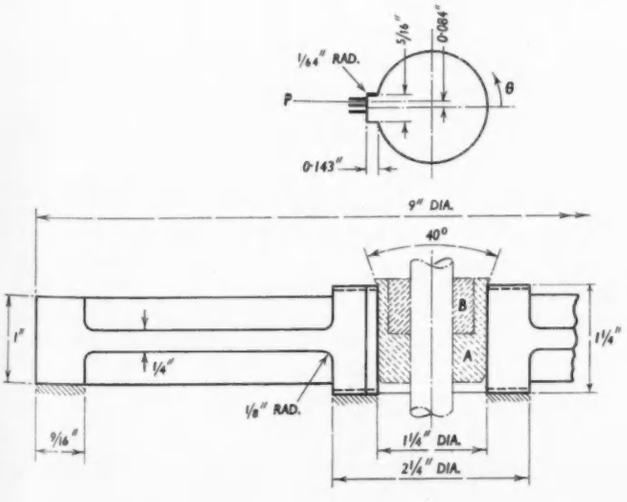


Fig. 1—Gear wheels. Models 1 and 2 shown by full lines. Model 3 shown by dotted lines

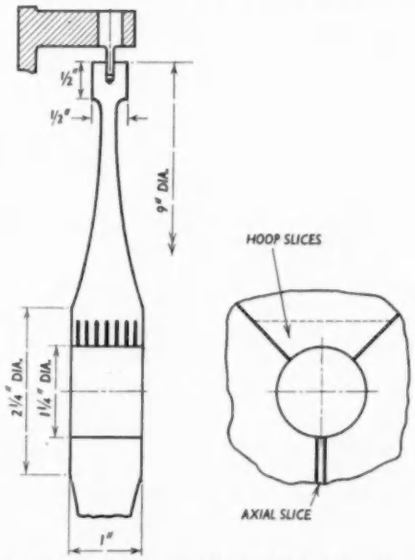


Fig. 2—Turbine disc, model 4. Thick lines show material removed in slitting

This latter model was used to compare the axial stresses at the keyways with the axial stresses at the bore.

Model 4, of hyperbolic profile, was intended to approximate to a turbine disc, and is shown in Fig. 2.

Experimental Procedure

All models were tested using the photo-elastic frozen stress technique, but the

Technical Contributors Section (*continued*)

method of location differed. Models 1-3 were rotated on a horizontal aluminium turntable and were located by a bush (*A* in Fig. 1) which was itself located on a central spindle. To maintain the concentricity of model and axis of rotation when the bore of the model expanded under the centrifugal action, the upper portion of the bush *A* was made conical with an included angle of 40 deg. A small steel weight *B* was used to ensure contact between the bush and wheel, but this method of location exerted a small axial and radial thrust at one edge of the bore. The clearance between the expanded bore and the bush during the stress freezing cycle ensured that the radial stress along the bore surface was zero, except at the corner where the locating bush was in contact. The rims of models 1-3 were supported on shims attached to the turntable to reduce deflections of the models due to their own weight to a negligible amount. This precaution was necessary because during the stress freezing cycle Young's modulus of the model material (Araldite Casting Resin B) is very low (approximately 2500 lb per square inch) compared to its density (approximately 0·044 lb per cubic inch).

Model 4 was rotated about a horizontal axis, located and driven at the rim as shown in Fig. 2. Four equispaced steel pins were held in projections from a vertical steel face plate. The pins fitted into radial holes in the periphery of the wheels. If holes and pins are truly radial and appropriately spaced, the wheel is fully located but free to expand. The bore is therefore completely free and so will show the presence of axial stresses without any effects of locating constraints which may be present with the other models. Free bores of discs occur in some turbines.

All wheels were rotated at appropriate constant speeds throughout the stress freezing cycle. Slices parallel to the axis were cut, from which the axial stresses were determined. The hoop stresses were derived from slices cut perpendicularly to the axis of the wheels. The positions of these slices may be seen in Fig. 2 where the very thick lines indicate material removed by the slitting wheel to obtain the required slices.

The density of the material of each wheel was measured by weighing in air and in water. The optical sensitivity (material fringe value) was determined from tensile calibration strips cut from each wheel.

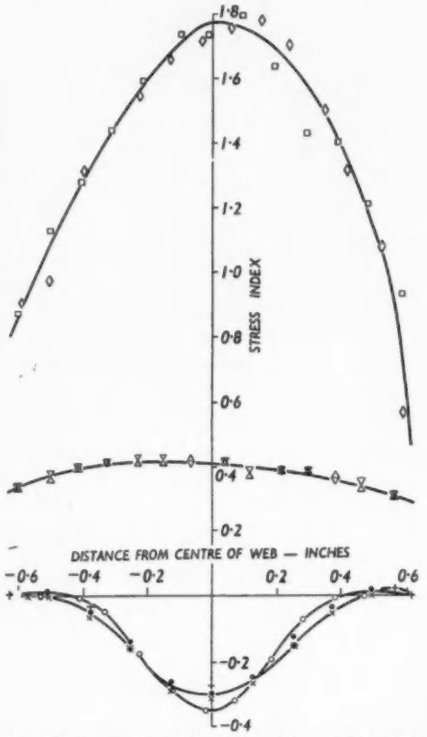
Presentation of Results

All results are presented as stress indices in a common non-dimensional form and plotted to the same scale to make them readily comparable. The stress indices are the measured stresses divided by the hoop stress at the bore of a thin disc of constant thickness which has the same bore and outside diameter as the wheel considered, is made of the same material and is rotating at the same speed. This bore hoop stress was calculated from the standard theory. At the bore, the hoop stress

$$\sigma_0=\frac{\rho\omega^2}{4}[(3+\upsilon)r_o^2+(1-\upsilon)r_i^2]$$

where

ρ=mass density of material.
ω=angular velocity
υ=Poisson's ratio
r_o=outside radius
r_i=inside radius.



△▽—Hoop stress in model 1 at θ=90 deg. and θ=270 deg. respectively.
□◇—Hoop stress in both keyway fillets of model 2.
+×—Axial stress in Model 1 at θ=0 deg. and θ=180 deg. respectively.
●—Axial stress in model 2 opposite keyway.
○—Axial stress at centre of keyway of model 2.

Fig. 3—Stresses in bores of gear wheels, models 1 and 2

Gear Wheels

Fig. 3 shows hoop and axial stresses in models 1 and 2 which are identical except for the keyway in model 2. The hoop stress in the bore is fairly constant, whereas the hoop stress in the fillets of the keyway shows a pronounced peak near the centre of the web. This peak stress is 4¼ times greater than the greatest hoop stress in the bore.

Large compressive axial stresses occur in the bore near the centre of the hub. The stresses opposite the keyway of model 2 agree very closely with the stresses at two positions in the plain bore of model 1. The greatest axial stress index is −0·3 at the central plane of the wheel; this is about three-quarters of the greatest hoop stress in the plain bore. The maximum shear stress at the bore is therefore about 75 per cent greater than would be predicted from calculation of the hoop stress only. Because the greatest difference of principal stresses corresponds to a stress index greater than 0·7 it is evident that the bosses of these models contribute little to a reduction of the peak stresses. (Such bosses are of course often necessary for location purposes.)

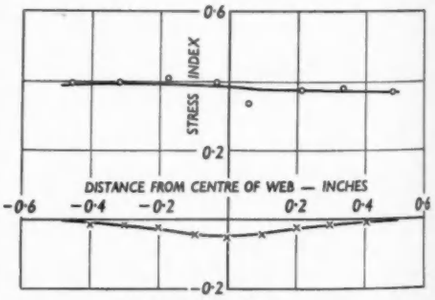
The axial stresses at the centre of the keyway of model 2 show a similar distribution to the stresses in the bore, but their maximum value is −0·35, one-sixth greater than the greatest compressive stresses in the bore.

The boss of model 3 was unfortunately shorter than those of models 1 and 2 and direct comparison with the results from those models is therefore not possible. However the two keyways of model 3 allowed examination of the axial stresses near the fillet (position *P* in Fig. 1) as well as at the centre of the keyway. Fig. 4 shows these axial stresses in addition to the axial stress at the bore midway between the keyways. The general stress distribution is similar to that in models 1 and 2. The stresses at the two positions in the keyway are similar and their maximum value is about one-quarter greater than the greatest axial compressive stress in the bore of this model. The increase of axial stress in the keyway compared with the plain bore is thus seen to be a feature of both wheels.

Because axial compressive stresses occur in the bore, at the centre of the keyway and away from the centre of the keyway, it is reasonable to assume that they occur at the keyway fillets also. As the distribution and magnitude of these axial stresses is very similar at the three positions considered, it will probably differ little at the keyway fillet. This results in an increase in shear stress at the fillets over the two-dimensional case which is usually considered. The greatest stress difference corresponds to a stress index of 2·1, indicating a very highly stressed region in these wheels.

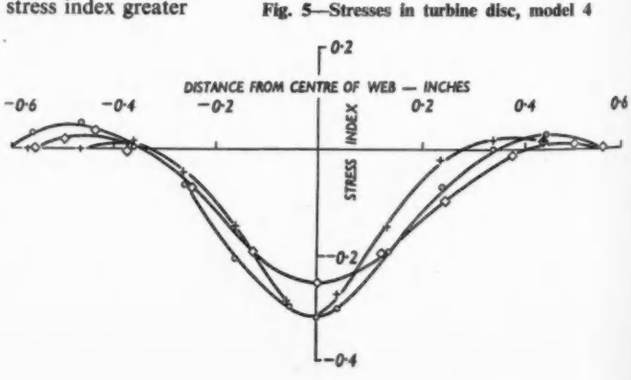
Turbine Disc

As is to be expected, due to the gradual change in thickness of this wheel, the hoop stress is constant, within the limits of experi-



○—Hoop stress in bore.
×—Axial stress in bore.

Fig. 5—Stresses in turbine disc, model 4



◇—Axial stress in bore between keyways.
○—Axial stress at centre of keyway.
+—Axial stress at *P*. (See Fig. 1(*a*)).

Fig. 4—Axial stresses in gear wheel, model 3

mental accuracy, along the length of the bore (Fig. 5).

However there still remains some axial compressive stress, again at the middle of the hub. Its maximum value is about one-ninth of the value of the hoop stress so that even with a hyperbolic type disc the maximum shear stress calculated in the usual manner is subject to an error of 10 per cent at the bore.

Conclusions

Axial compressive stresses have been shown to occur where a rotating hub is non-uniformly loaded (in the axial direction). These stresses are small but not negligible for discs of hyperbolic profile, but they are of the same order of magnitude (and opposite sign) as the hoop stresses in the bore for wheels which consist of cylindrical bosses with flat plate webs. Normal calculations which ignore these axial stresses may seriously underestimate the actual critical stresses.

Where keyways are present, the axial stresses are increased somewhat. These axial compressive stresses occur also near the fillets of the keyway where large tensile hoop stresses exist.

Axial compressive stresses are associated with variations of hoop stress ; their maximum values occur at the centre of the web. This stress distribution suggests that the web expands the bore of the hub, which assumes a barrel shape.

Acknowledgments

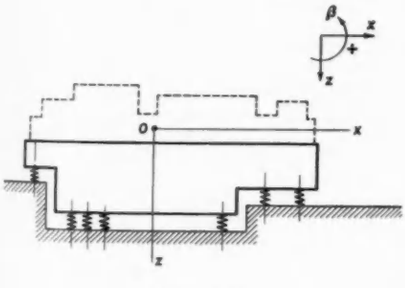
The authors wish to thank Professor J. A. Pope who, as Head of the Department of Mechanical Engineering, provided the necessary facilities for this work. They are indebted to Mr. L. D. McConnell of Rolls-Royce, Ltd., Derby, who first drew their attention to the phenomenon of axial compressive stresses and who suggested the method of rim location.

Natural Frequencies of Large Seismic Mountings on Non-Coplanar Isolators

By J. WALDERSEE*

Expressions are derived for the natural frequencies of a body seismically mounted on a non-coplanar arrangement of isolators. They are compared with similar expressions derived by Macinante† for coplanar isolators.

In a recent article†, Macinante (1960) derived expressions for the natural frequencies of seismic mountings on isolators that are in a common horizontal plane. The purpose of the present note is to extend the results to mountings in which the isolators are not in a common plane (See Fig. 1).



Notation

The notation used is the same as that in Macinante's paper with the following exceptions :

X_r, Y_r, Z_r are the co-ordinates of the rth isolator with reference to the axes Ox, Oy, Oz respectively ; $\bar{X}$, $\bar{Y}$, $\bar{Z}$ are the root-mean-square distances of isolators from the yz, xz and xy planes respectively ; Z_m is the mean distance of isolators from the xy plane.

The symbol Z which previously denoted the (constant) vertical distance from the xy plane to the horizontal elastic plane of the isolators is not used as the isolators are no longer coplanar. For coplanar isolators, the distance Z is obviously the same as that denoted in the present paper by $\bar{Z}$.

*Division of Metrology, National Standards Laboratory, C.S.I.R.O., University Grounds, City Road, Chippendale, N.S.W., Australia.

Mounting Conditions

The assumptions made in Macinante's paper are also made here, with the exception of that restricting the isolators to a common plane. Briefly, these are that all isolators have the same stiffness properties, that the isolator stiffness in any horizontal direction has a constant ratio to the vertical stiffness, that the motion can be linearised for small vibrations about the equilibrium position, and that the conditions are fulfilled for equal load-sharing and for absence of "cross-coupling" about horizontal axes.

Natural Frequencies

The natural frequencies of a body mounted on an unsymmetrical arrangement of isolators fulfilling the stated conditions may be derived using the same method as that adopted by Macinante.

(1) *Uncoupled Modes.*—Since the vertical free vibration and the rotational mode about the vertical axis are uncoupled and are independent of the z co-ordinate of the isolators, the expressions for these frequencies using a non-coplanar arrangement of isolators are the same as those derived in the earlier paper, viz :

$$\Omega_z=\sqrt{\left(\frac{nk_z}{M}\right)}$$

$$\Omega_\gamma=\sqrt{\left\{\frac{k_{xy}n(\bar{X}^2+\bar{Y}^2)}{I_z}\right\}}$$

(2) *Coupled Modes in xz plane.*—Let the body perform a simple rocking motion in the xz plane. At a given instant the centre of gravity is displaced by small amounts x and z which are positive and the body has rotated an amount β which is negative, using the sign convention of the previous paper. For small values of β, the horizontal deflection of the rth isolator can be written $x+z_r\beta$, which is valid for positive and negative values of z_r.

Thus, the equation of x motion is

$$M\ddot{x}=-k_{xy}\Sigma_n(x+z_r\beta) \quad . \; . \; (1)$$

The moment about Oy of the horizontal forces at the isolators is

$$-k_{xy}\Sigma_r z_r(x+z_r\beta)$$

The vertical deflection of any isolator, again for small β, is $z-x_r\beta$. However, since the vertical vibration is uncoupled the z component does not affect the rotation. Hence, omitting z, the moment due to the vertical deflection of the isolators caused by the rotation β is

$$-k_z\beta\Sigma_n x_r^2$$

i.e.

$$-k_z\beta_n\bar{X}^2$$

The equation for the β motion becomes

$$I_y\ddot{\beta}=-k_{xy}\Sigma_n z_r(x+z_r\beta)-nk_z\bar{X}^2\beta \; . \quad (2)$$

Since it is known that the periodic x displacement of the centre of gravity and the coupled β rotation take place at the same frequency, this will be denoted by Ωc. Motion can be maintained in either of two modes, i.e. β a maximum (positive or negative) when x is a maximum (positive). Thus, it is assumed that

$$x=x_o\sin\Omega_c t \qquad \beta=\pm\beta_o\sin\Omega_c t$$

$$\ddot{x}=-\Omega_c^2x_o\sin\Omega_c t \qquad \ddot{\beta}=\mp\Omega_c^2\beta_o\sin\Omega_c t$$

Substituting in Equations (1) and (2) and re-arranging, the equations to be satisfied become

$$(-M\Omega_c^2+nk_{xy})x_o\pm(k_{yx}\Sigma_n z_r)\beta_o=0$$

$$(k_{xy}\Sigma_n z_r)x_o\mp(I_y\Omega_c^2\mp k_{xy}\Sigma_n z_r^2\mp nk_z\bar{X}^2)\beta_o=0$$

Further substituting

$$\eta=k_{xy}/k_z,\; I_y=M\rho_y^2,\; \Omega_z^2=nk_z/M,$$

we have

$$\left(-\frac{\Omega_c^2}{\Omega_z^2}+\eta\right)x_o\pm\left(\eta\frac{\Sigma_n z_r}{n}\right)\beta_o=0$$

$$\left(\eta\frac{\Sigma_n z_r}{n}\right)x_o\mp\left(\rho_y^2\frac{\Omega_c^2}{\Omega_z^2}\mp\eta\frac{\Sigma_n z_r^2}{n}\mp\bar{X}^2\right)\beta_o=0$$

Eliminating either x_o or β_o in these equations and introducing

$$\bar{Z}^2=\frac{\Sigma_n z_r^2}{n} \text{ and } Z_m=\frac{\Sigma_n z_r}{n},$$

$$\left(\frac{\Omega_c}{\Omega_z}\right)^4-\left\{\eta\left(1+\frac{\bar{Z}^2}{\rho_y^2}\right)+\frac{\bar{X}^2}{\rho_y^2}\right\}\left(\frac{\Omega_c}{\Omega_z}\right)^2+\frac{\eta}{\rho_y^2}\left\{\bar{X}^2-\eta(Z_m^2-\bar{Z}^2)\right\}=0$$

The solution to this equation is

$$\left(\frac{\Omega_c}{\Omega_z}\right)^2=\frac{1}{2}\left(\xi\pm\sqrt{\left[\xi^2-\frac{4\eta}{\rho_y^2}\left\{\bar{X}^2-\eta(Z_m^2-\bar{Z}^2)\right\}\right]}\right)$$

in which

$$\xi=\eta\left(1+\frac{\bar{Z}^2}{\rho_y^2}\right)+\frac{\bar{X}^2}{\rho_y^2}$$

(3) *Coupled Modes in yz Plane.*—An analogous expression may be written down for the coupled modes in the yz plane with the appropriate changes of symbols.

Conclusion

It has been found that the expressions for the coupled modes with non-coplanar isolators differ from those given by Macinante for coplanar isolators in the following respects :

(i) Z, the constant distance of the coplanar isolators from the xy plane is replaced by $\bar{Z}$ the r.m.s. distance of the non-coplanar isolators.

(ii) The discriminant now contains a term in $Z_m^2-\bar{Z}^2$. For coplanar isolators $Z_m=\bar{Z}$ and this term disappears.

†Macinante, J. A. "Seismic Mountings for Large Machine Tools," THE ENGINEER, November 25, 1960, page 880.

Technical Contributors Section (*continued*)

Graphical Design of Tubular Heat Exchangers

By J. STARCZEWSKI

Normally the maximum allowable pressure drop (ΔP) on shell and tube sides and the heat duty (B.Th.U. per hour) are known. The problem is to find the minimum size of heat exchanger that would be suitable for this specified duty and ΔP. When designing heat exchangers by calculations one assumes heat exchanger size, baffle pitch and number of shell and tube passes. Then R_e, P_r, A_s, ΔP and heat transfer on shell and tube sides are calculated and compared with the specified ΔP and heat transfer. This process is repeated until the optimum heat exchanger is reached. The method is laborious and time-consuming. The time-saving graphical method described applies to gases and liquids under viscous or turbulent flow conditions, when there is no phase change. Baffle pitch should be between $d_s/5$ and d_s. The correlations hold for 25 per cent cut segmental baffles.

FOUR graphs are used (facing this page) two for pressure drop on shell and tube sides and two for heat transfer on shell and tube sides. All possible data of a particular fluid and of heat exchanger dimensions are collected and calculated as a characteristic quantity, which becomes constant for the fluid in question. For any assumed heat exchanger it is quickly seen from the graphs whether the flow arrangement and surface satisfy the heat duty and ΔP requirements. This method takes only a fraction of the time taken by the usual method of calculation.

Shell-Side Pressure Drop

The pressure drop is given by :

$$\Delta P_s = \frac{f_s G_s^2 D_s (N+1)}{5{\cdot}22\ 10^{10}\left(\frac{\mu}{\mu_w}\right)^{0{\cdot}14} De\gamma}\ \frac{1^*}{}\ \text{pounds per square inch} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where

$$\left(\frac{\mu}{\mu_w}\right)$$

is the ratio of the viscosities at the pipe wall temperature and at the calorific temperature ; and

$$\left(\frac{\mu}{\mu_w}\right)^{0{\cdot}14}$$

for many cases can be approximated to unity; also

$$D_s = \frac{d_s}{12}\ ;\ (N+1) = \frac{12L}{B} \text{ and } G_s = \frac{W_s}{A_s} = \frac{W_s 144 T_p N_s}{d_s C' B}$$

$$\Delta P_s = f_s\left[\frac{12 \times 144^2 L}{6{\cdot}26\ 10^{11} De\gamma}\left(\frac{T_p W_s}{C'}\right)^2 \frac{N_s^2}{d_s B^3}\right] \quad . \quad (2)$$

and

$$f_s = f(Re) = f\left(\frac{DeG_s}{2{\cdot}42\mu}\right) = f\left(\frac{144 DeT_p W_s}{2{\cdot}42\mu C'}\ \frac{N_s}{d_s B}\right) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$\Delta P_s = \left[\frac{12 \times 144^2 L}{6{\cdot}26 \times 10^{11} De\gamma}\left(\frac{T_p W_s}{C'}\right)^2\right]\frac{N_s^2}{d_s B^3} f\left[\left(\frac{144 DeT_p W_s}{2{\cdot}42\mu C'}\right)\frac{N_s}{d_s B}\right]$$

$$\left[3{\cdot}98\ 10^{-7}\frac{L}{De}\frac{1}{\gamma}\left(\frac{T_p W_s}{C'}\right)^2\right]\frac{N_s^2}{d_s B^3} f\left[\delta_1 \frac{N_s}{d_s B}\right]$$

$$= z_0 \frac{N_s^2}{d_s B^3} f\left[\delta_1 \frac{N_s}{d_s B}\right] \text{ pounds per square inch} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

For a particular fluid both z_0 and δ_1 are constant, because, for practical considerations, L, P_T, d_o are fixed.

In effect we are left with five variables for a general case and with three variables for a particular case.

* Defined by "Process Heat Transfer" by Kern

Shell Side Heat Transfer

For forced fluid flow the following relationship applies :

$$Nu = \alpha Re Pr^{\frac{1}{3}}\left(\frac{\mu}{\mu_w}\right)^{0{\cdot}14} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and heat transfer factor J_H* is defined as :—

$$\left(\frac{hD}{k}\right)\left(\frac{2{\cdot}42\mu c}{k}\right)^{-\frac{1}{3}}\left(\frac{\mu}{\mu_w}\right)^{0{\cdot}14} \quad . \quad . \quad (6)$$

$$\left(\frac{\mu}{\mu_w}\right)^{0{\cdot}14}$$

is approximated to unity, from (6)

$$h_s = \frac{k}{D_e}\left(\frac{2{\cdot}42\mu c}{k}\right)^{\frac{1}{3}} J_H \quad . \quad . \quad . \quad . \quad . \quad (7)$$

But

$$J_H = f(Re)$$

from (3) and (4)

$$J_H = f\left(\delta_1 \frac{N_s}{d_s B}\right).$$

Resistance to heat flow S_s is defined by :

$$S_s = \frac{1000}{h_s} = \left(\frac{1000}{\frac{k}{De}\left(\frac{2{\cdot}42\mu c}{k}\right)^{\frac{1}{3}}}\right)\frac{1}{f\left(\delta_1 \frac{N_s}{d_s B}\right)} = \frac{\rho_1}{f\left(\delta_1 \frac{N_s}{d_s B}\right)} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where ρ_1 and δ_1 are constants for a particular fluid.

Tube Side Pressure Drop

From Fanning Equation :

$$\Delta F = \frac{4 C_f G^2 l}{2g\varepsilon D} \text{ pounds per square foot per tube pass} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

G_T is in pounds per hour, therefore,

$$\Delta F = \frac{4 C_f G_T^2 L}{64{\cdot}4 \times 6{\cdot}4\gamma(3600)^2 D}\ \frac{1}{144} \text{ pounds per square inch per tube pass}$$

$$= \frac{4 C_f G_T^2 L}{7{\cdot}48\ 10^{12}\gamma D} \text{ pounds per square inch per tube pass.}$$

Assuming that the losses due to expansion, contraction and fittings are equal to :

$$3{\cdot}5\frac{G_T^2}{7{\cdot}48\ 10^{12}\gamma} \text{ pounds per square inch per tube pass,}$$

hence, total pressure drop,

$$\Delta P_T = \frac{N_T G_T^2}{7{\cdot}48\gamma 10^{12}}\left[L\frac{4C_f}{D} + 3{\cdot}5\right] \text{ pounds per square inch.}$$

Including a 25 per cent safety factor and adopting a new friction factor,

$$f_T = \frac{1{\cdot}25 \times 4}{7{\cdot}48}\frac{C_f}{D} \text{ we get :}$$

$$\Delta P_T = \frac{N_T G_T^2}{\gamma 10^{12}}[Lf_T + 0{\cdot}6] \quad . \quad . \quad . \quad . \quad . \quad (10)$$

But $f_T = f(Re,\ D)$ and for a particular tube $f_T = f(Re)$.

Nomenclature: see drawings (a) (b) (c) below.—

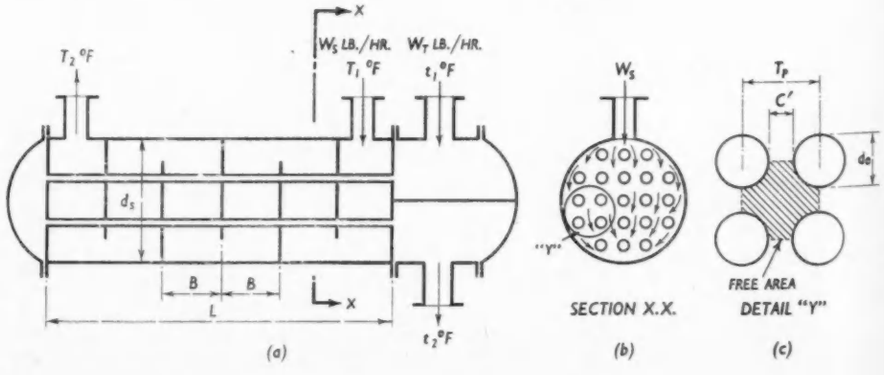
De—Shell equivalent diameter in feet.*

$$De = 4\frac{\text{free area}}{\text{wetted perimeter}}, \text{ for the above case}$$

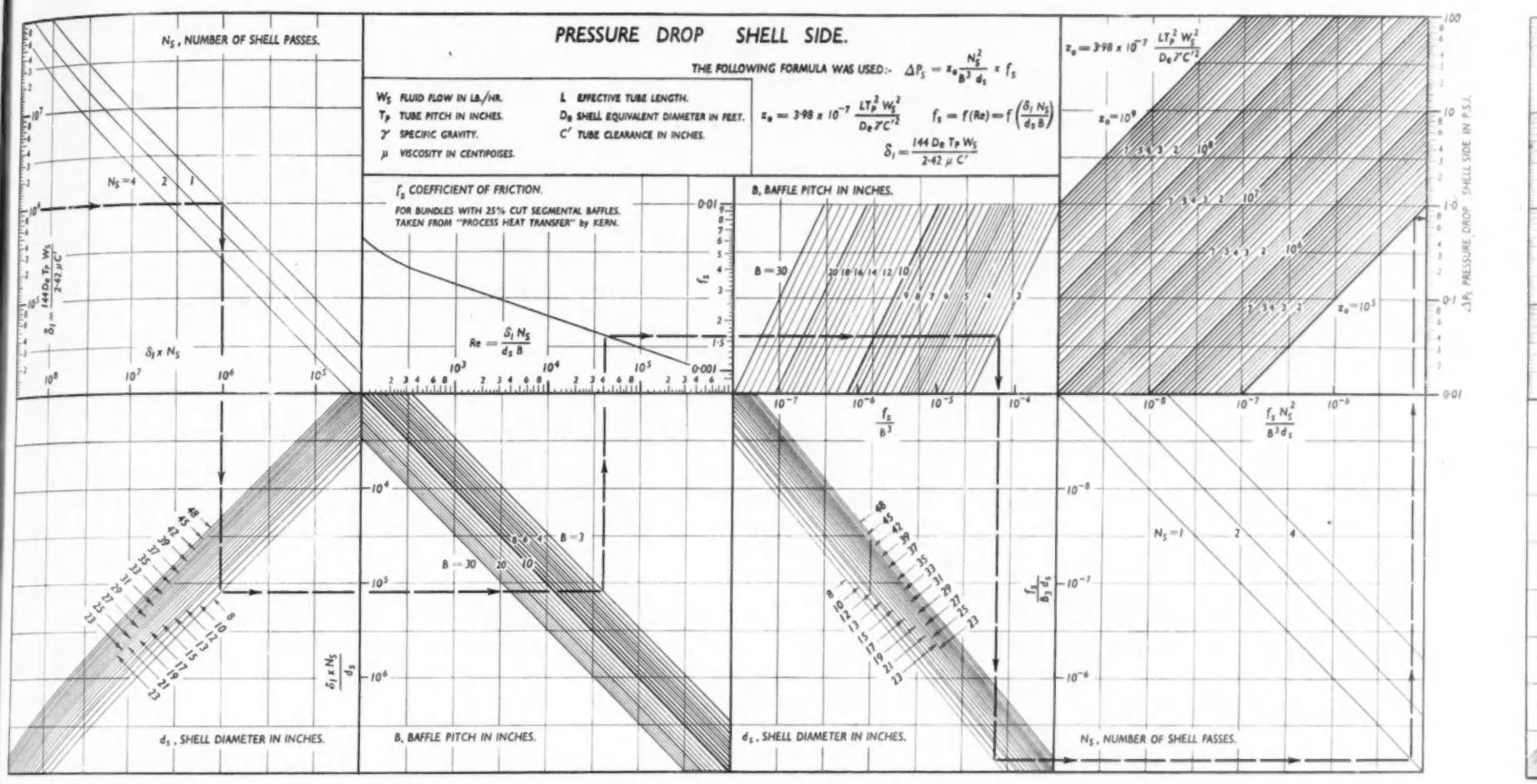
$$= 4\frac{[T_p^2 - \pi d_o^2/4]}{4[\pi d_o/4]}\ \frac{1}{12} \text{ ft.}$$

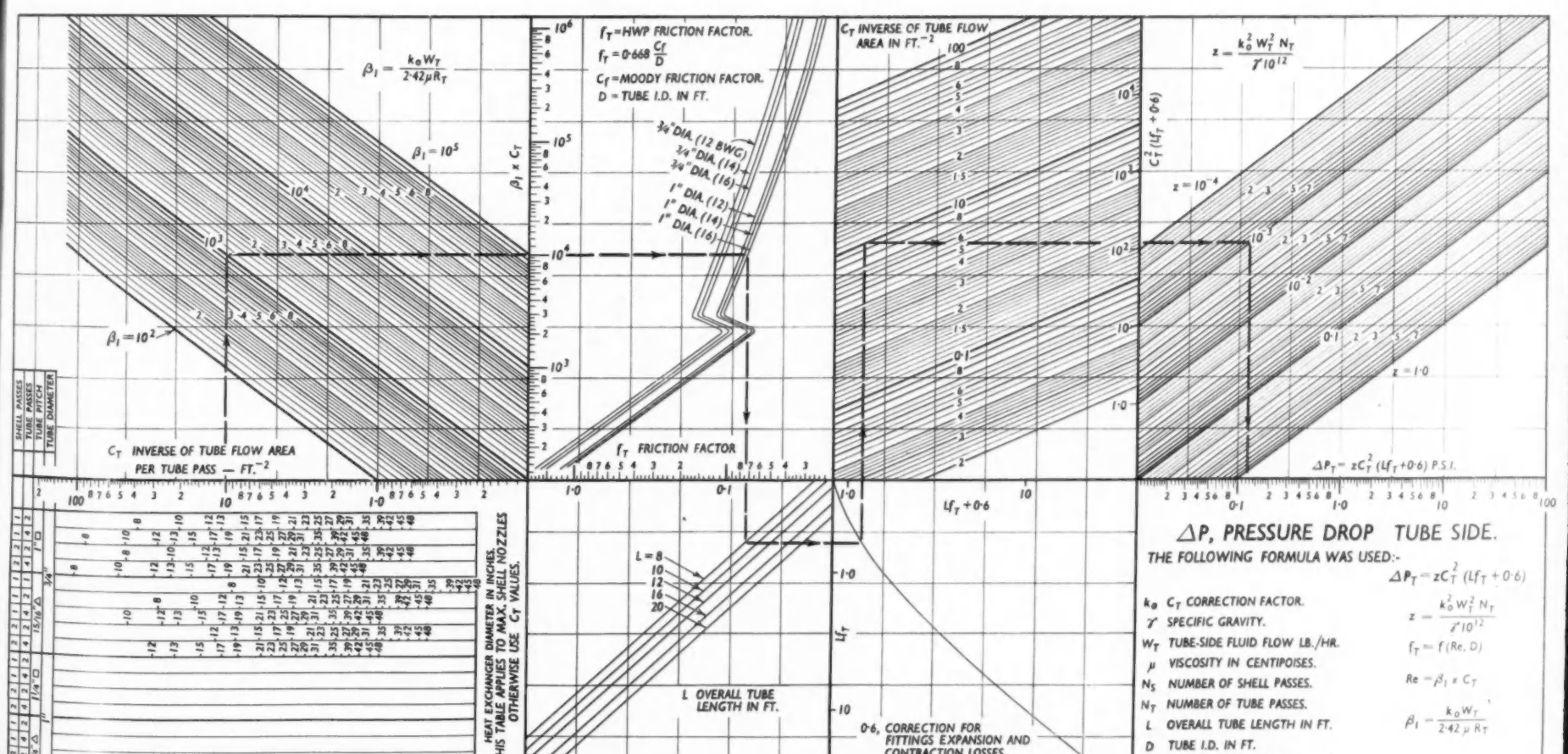
A_s—Shell-side cross flow area in feet²* $\left(= \frac{d_s C' B}{T_p N_s}\ \frac{1}{144}\right)$

C'—Tube clearance in inches.
T_p—Tube pitch in inches.
B—Baffle pitch in inches.
L—Tube length in feet.
d_s—Exchanger inside diameter in inches.
$(N+1)$—Number of passes between baffles.
A_1—Heat flow area per foot of tube length in feet².
C_T—Inverse of tube flow area per tube pass in feet⁻².
ko—C_T correction factor.
D—Tube I/D in feet.
R_T—Inverse of tube I/D in feet⁻¹.
W_s—Fluid flow in pounds per hour.
G—Mass velocity in pounds per hour foot².
μ—Viscosity in centipoises.
c—Specific heat in B.Th.U. per pound, deg. Fah.
γ—Specific gravity.
ξ—Density, pounds per foot³.
k—Thermal conductivity in $\frac{\text{B.Th.U.}}{\text{hours feet}^2}\ \frac{\text{feet.}}{\text{deg. Fah.}}$
Q—Heat load in B.Th.U. per hour.
U—Overall heat transfer coefficient in $\frac{\text{B.Th.U.}}{\text{hours feet}^2}$ deg. Fah.
S—Resistance to heat flow in $\frac{\text{hours feet}^2 \text{ deg. Fah.}}{\text{B.Th.U.}}$
h—Individual heat transfer coefficient between fluid and surface in $\frac{\text{B.Th.U.}}{\text{Hours feet}^2 \text{ deg. Fah.}}$
ΔT—Logarithmic-mean overall temperature difference.
E—Temperature correction factor for multi-pass heat exchanger.
s—Prefix, indicates shell-side.
t—Prefix, indicates tube-side.
Nu—Nusselt number.
Pr—Prandtl number.
Re—Reynolds number.



GRAPHICAL DESIGN OF TUBULAR H


PRESSURE DROP SHELL SIDE.
THE FOLLOWING FORMULA WAS USED:- $\Delta P_S = z_o \frac{N_S^2}{B^3 d_s} \times f_s$
W_S FLUID FLOW IN LB./HR.
T_p TUBE PITCH IN INCHES.
γ SPECIFIC GRAVITY.
μ VISCOSITY IN CENTIPOISES.
L EFFECTIVE TUBE LENGTH.
D_e SHELL EQUIVALENT DIAMETER IN FEET.
C' TUBE CLEARANCE IN INCHES.
$z_o = 3{\cdot}98 \times 10^{-7} \frac{LT_p^2 W_S^2}{D_e \gamma C'^2}$
$f_s = f(Re) = f\left(\frac{\delta_1 N_S}{d_s B}\right)$
$\delta_1 = \frac{144 D_e T_p W_S}{2{\cdot}42 \mu C'}$
N_S, NUMBER OF SHELL PASSES.
f_s COEFFICIENT OF FRICTION.
FOR BUNDLES WITH 25% CUT SEGMENTAL BAFFLES.
TAKEN FROM "PROCESS HEAT TRANSFER" by KERN.
B, BAFFLE PITCH IN INCHES.
ΔP_S, PRESSURE DROP SHELL SIDE IN P.S.I.
d_s, SHELL DIAMETER IN INCHES.
B, BAFFLE PITCH IN INCHES.
d_s, SHELL DIAMETER IN INCHES.
N_S, NUMBER OF SHELL PASSES.


$\beta_1 = \frac{k_o W_T}{2{\cdot}42 \mu R_T}$
C_T INVERSE OF TUBE FLOW AREA PER TUBE PASS — FT.$^{-2}$
f_T=HWP FRICTION FACTOR.
$f_T = 0{\cdot}668 \frac{C_f}{D}$
C_f=MOODY FRICTION FACTOR.
D = TUBE I.D. IN FT.
f_T FRICTION FACTOR
C_T INVERSE OF TUBE FLOW AREA IN FT.$^{-2}$
$z = \frac{k_o^2 W_T^2 N_T}{\gamma^2 10^{12}}$
$\Delta P_T = z C_T^2 (Lf_T + 0{\cdot}6)$ P.S.I.
L OVERALL TUBE LENGTH IN FT.
0·6, CORRECTION FOR FITTINGS EXPANSION AND CONTRACTION LOSSES.
HEAT EXCHANGER DIAMETER IN INCHES.
THIS TABLE APPLIES TO MAX. SHELL NOZZLES OTHERWISE USE C_T VALUES.
SHELL PASSES
TUBE PASSES
TUBE PITCH
TUBE DIAMETER

ΔP, PRESSURE DROP TUBE SIDE.

THE FOLLOWING FORMULA WAS USED:-

$$\Delta P_T = z C_T^2 (Lf_T + 0{\cdot}6)$$

k_o	C_T CORRECTION FACTOR.
γ	SPECIFIC GRAVITY.
W_T	TUBE-SIDE FLUID FLOW LB./HR.
μ	VISCOSITY IN CENTIPOISES.
N_S	NUMBER OF SHELL PASSES.
N_T	NUMBER OF TUBE PASSES.
L	OVERALL TUBE LENGTH IN FT.
D	TUBE I.D. IN FT.
R_T	INVERSE OF TUBE I.D. IN FT.$^{-1}$

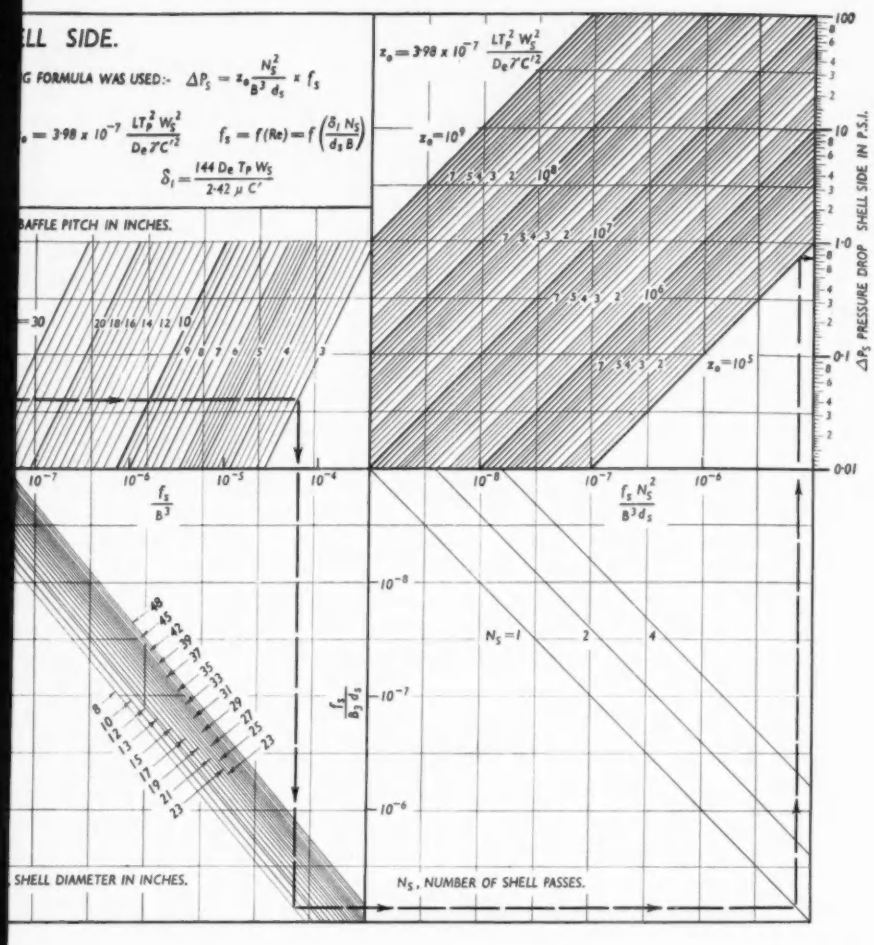
$$z = \frac{k_o^2 W_T^2 N_T}{\gamma^2 10^{12}}$$

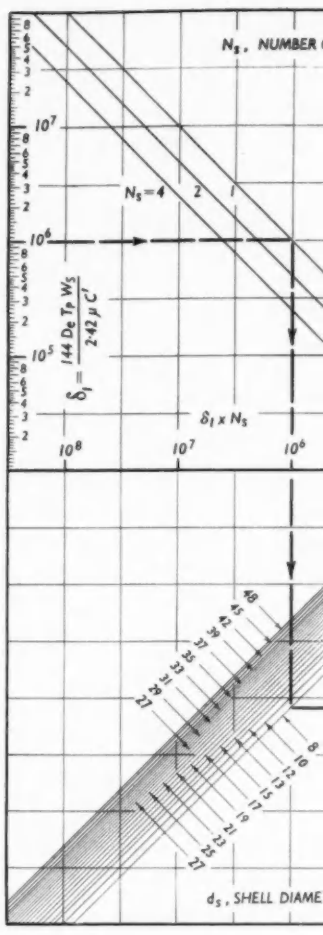
$f_T = f(Re, D)$

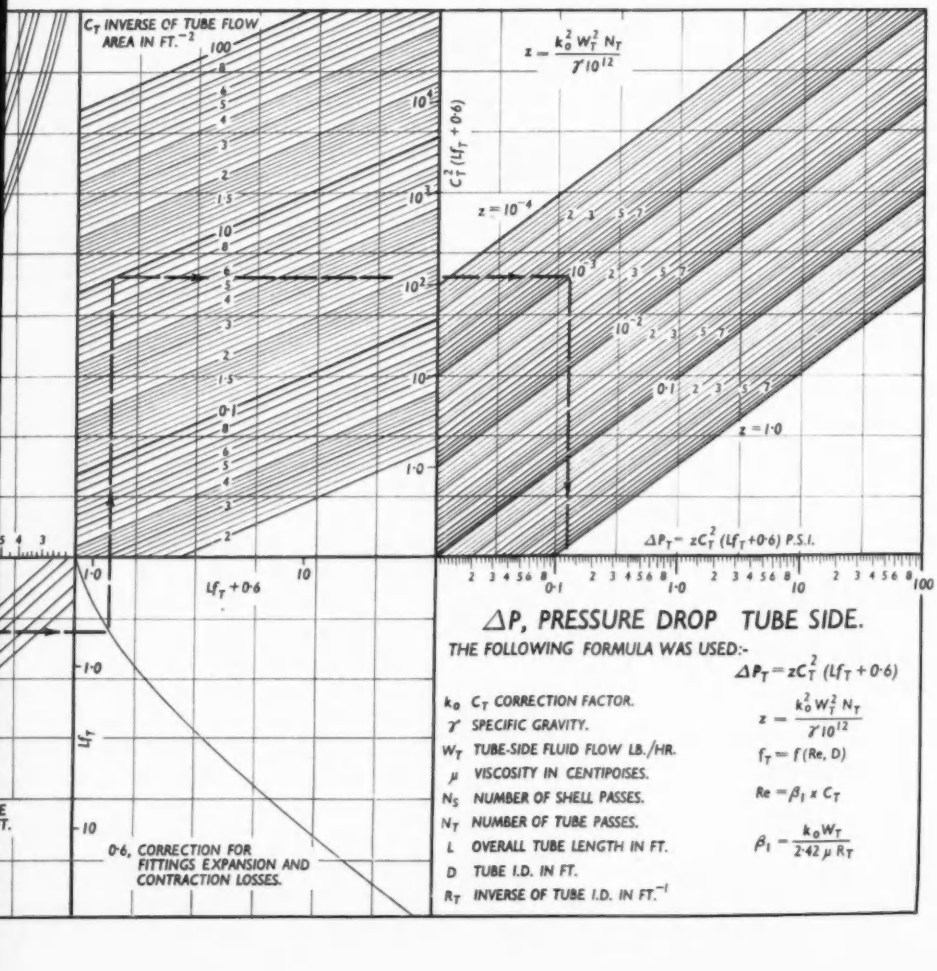
$Re = \beta_1 \times C_T$

$$\beta_1 = \frac{k_o W_T}{2{\cdot}42 \mu R_T}$$

PHICAL DESIGN OF TUBULAR HEAT EXC


LL SIDE.
G FORMULA WAS USED:- $\Delta P_S = z_o \frac{N_S^2}{B^3 d_s} \times f_s$
$z_o = 3{\cdot}98 \times 10^{-7} \frac{LT_p^2 W_s^2}{D_e \gamma' C'^2}$ $f_s = f(Re) = f\left(\frac{\delta_1 N_S}{d_s B}\right)$
$\delta_1 = \frac{144\, D_e\, T_p\, W_S}{2{\cdot}42\, \mu\, C'}$
BAFFLE PITCH IN INCHES.
SHELL DIAMETER IN INCHES.
N_S, NUMBER OF SHELL PASSES.
ΔP_S PRESSURE DROP SHELL SIDE IN P.S.I.




C_T INVERSE OF TUBE FLOW AREA IN FT.$^{-2}$
$z = \frac{k_o^2 W_T^2 N_T}{\gamma' 10^{12}}$
$C_T^2 (Lf_T + 0{\cdot}6)$
$\Delta P_T = zC_T^2 (Lf_T + 0{\cdot}6)$ P.S.I.
$Lf_T + 0{\cdot}6$
$L f_T$
0·6, CORRECTION FOR FITTINGS EXPANSION AND CONTRACTION LOSSES.

ΔP, PRESSURE DROP TUBE SIDE.

THE FOLLOWING FORMULA WAS USED:-

$$\Delta P_T = zC_T^2 (Lf_T + 0{\cdot}6)$$

k_o	C_T CORRECTION FACTOR.
γ'	SPECIFIC GRAVITY.
W_T	TUBE-SIDE FLUID FLOW LB./HR.
μ	VISCOSITY IN CENTIPOISES.
N_S	NUMBER OF SHELL PASSES.
N_T	NUMBER OF TUBE PASSES.
L	OVERALL TUBE LENGTH IN FT.
D	TUBE I.D. IN FT.
R_T	INVERSE OF TUBE I.D. IN FT.$^{-1}$

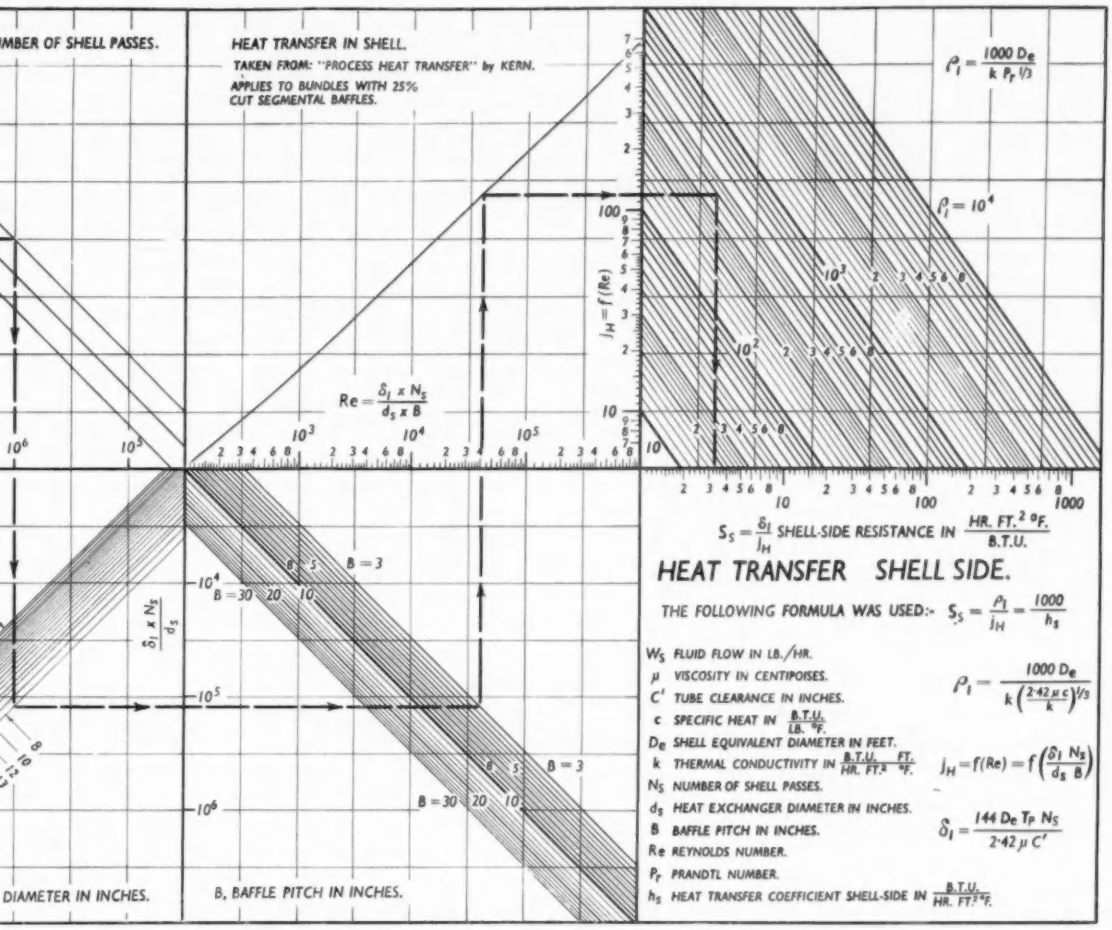
$$z = \frac{k_o^2 W_T^2 N_T}{\gamma' 10^{12}}$$

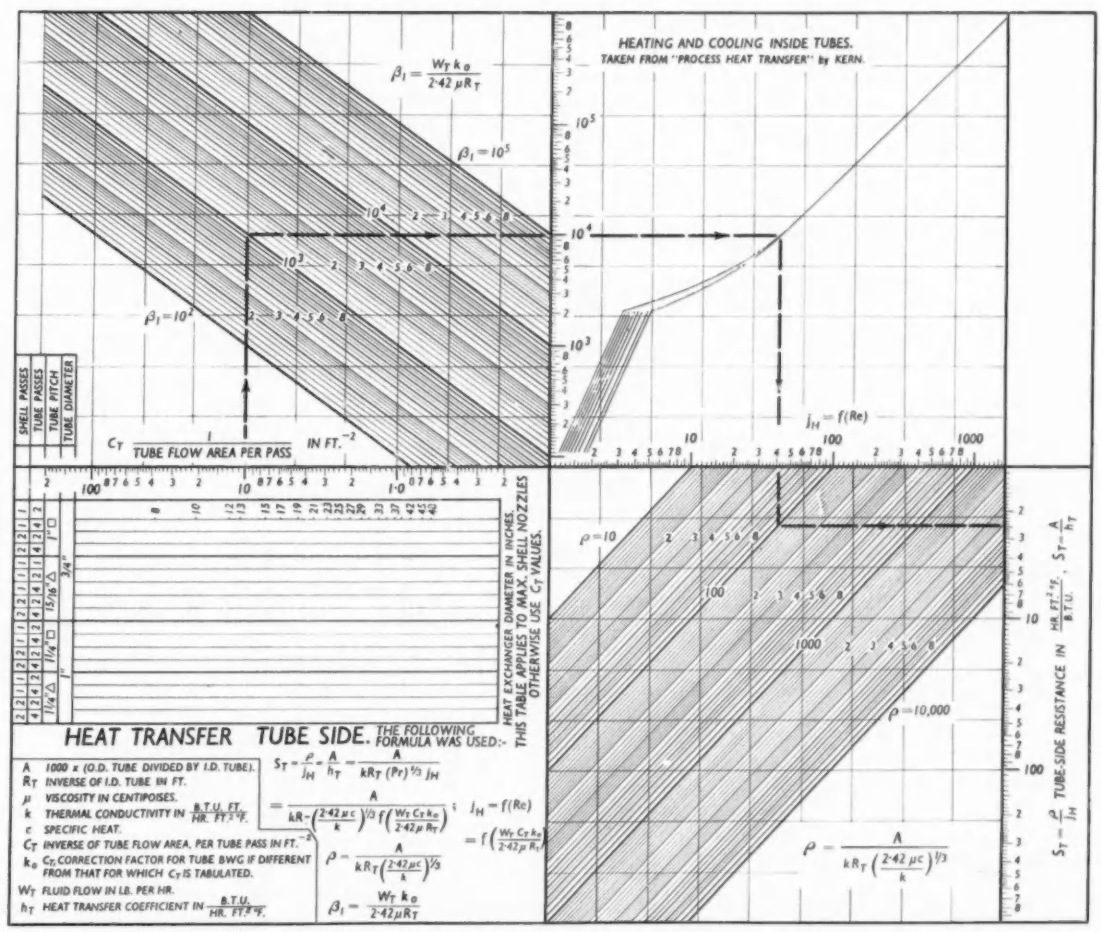
$$f_T = f(Re, D)$$

$$Re = \beta_1 \times C_T$$

$$\beta_1 = \frac{k_o W_T}{2{\cdot}42\, \mu\, R_T}$$

CHANGERS


NUMBER OF SHELL PASSES.
HEAT TRANSFER IN SHELL.
TAKEN FROM: "PROCESS HEAT TRANSFER" by KERN.
APPLIES TO BUNDLES WITH 25% CUT SEGMENTAL BAFFLES.
$\rho_1 = \frac{1000\ D_e}{k\ P_r^{1/3}}$
$\rho_1 = 10^4$
$j_H = f(Re)$
$Re = \frac{\delta_1 \times N_S}{d_s \times B}$
$\frac{\delta_1 \times N_S}{d_s}$
B = 30 20 10 8 5 3
$S_S = \frac{\delta_1}{j_H}$ SHELL-SIDE RESISTANCE IN $\frac{HR.\ FT.^2\ ^\circ F.}{B.T.U.}$
HEAT TRANSFER SHELL SIDE.
THE FOLLOWING FORMULA WAS USED:- $S_S = \frac{\rho_1}{j_H} = \frac{1000}{h_s}$
W_S FLUID FLOW IN LB./HR.
μ VISCOSITY IN CENTIPOISES.
C' TUBE CLEARANCE IN INCHES.
c SPECIFIC HEAT IN $\frac{B.T.U.}{LB.\ ^\circ F.}$
D_e SHELL EQUIVALENT DIAMETER IN FEET.
k THERMAL CONDUCTIVITY IN $\frac{B.T.U.}{HR.\ FT.^2\ ^\circ F.}\frac{FT.}{}$
N_S NUMBER OF SHELL PASSES.
d_s HEAT EXCHANGER DIAMETER IN INCHES.
B BAFFLE PITCH IN INCHES.
Re REYNOLDS NUMBER.
P_r PRANDTL NUMBER.
h_s HEAT TRANSFER COEFFICIENT SHELL-SIDE IN $\frac{B.T.U.}{HR.\ FT.^2\ ^\circ F.}$
$\rho_1 = \frac{1000\ D_e}{k\left(\frac{2{\cdot}42\ \mu\ c}{k}\right)^{1/3}}$
$j_H = f(Re) = f\left(\frac{\delta_1\ N_S}{d_s\ B}\right)$
$\delta_1 = \frac{144\ D_e\ T_P\ N_S}{2{\cdot}42\ \mu\ C'}$
DIAMETER IN INCHES.
B, BAFFLE PITCH IN INCHES.


$\beta_1 = \frac{W_T\ k_o}{2{\cdot}42\ \mu R_T}$
$\beta_1 = 10^5$
$\beta_1 = 10^2$
HEATING AND COOLING INSIDE TUBES.
TAKEN FROM "PROCESS HEAT TRANSFER" by KERN.
$j_H = f(Re)$
C_T $\frac{1}{\text{TUBE FLOW AREA PER PASS}}$ IN FT.$^{-2}$
SHELL PASSES
TUBE PASSES
TUBE PITCH
TUBE DIAMETER
HEAT EXCHANGER DIAMETER IN INCHES.
THIS TABLE APPLIES TO MAX. SHELL NOZZLES OTHERWISE USE C_T VALUES.
$\rho = 10$
$\rho = 10{,}000$
$S_T = \frac{\rho}{j_H}$ TUBE-SIDE RESISTANCE IN $\frac{HR.\ FT.^2\ ^\circ F.}{B.T.U.}$, $S_T = \frac{A}{h_T}$
HEAT TRANSFER TUBE SIDE.
THE FOLLOWING FORMULA WAS USED:-
$S_T = \frac{\rho}{j_H} = \frac{A}{h_T} = \frac{A}{kR_T\ (Pr)^{1/3}\ j_H}$
$= \frac{A}{kR \cdot \left(\frac{2{\cdot}42\ \mu\ c}{k}\right)^{1/3} f\left(\frac{W_T\ C_T\ k_o}{2{\cdot}42\ \mu\ R_T}\right)}$; $j_H = f(Re)$
$= f\left(\frac{W_T\ C_T\ k_o}{2{\cdot}42\ \mu\ R_T}\right)$
$\rho = \frac{A}{kR_T\left(\frac{2{\cdot}42\ \mu c}{k}\right)^{1/3}}$
$\beta_1 = \frac{W_T\ k_o}{2{\cdot}42\ \mu R_T}$
A 1000 x (O.D. TUBE DIVIDED BY I.D. TUBE).
R_T INVERSE OF I.D. TUBE IN FT.
μ VISCOSITY IN CENTIPOISES.
k THERMAL CONDUCTIVITY IN $\frac{B.T.U.\ FT.}{HR.\ FT.^2\ ^\circ F.}$
c SPECIFIC HEAT.
C_T INVERSE OF TUBE FLOW AREA, PER TUBE PASS IN FT.$^{-2}$
k_o C_T CORRECTION FACTOR FOR TUBE BWG IF DIFFERENT FROM THAT FOR WHICH C_T IS TABULATED.
W_T FLUID FLOW IN LB. PER HR.
h_T HEAT TRANSFER COEFFICIENT IN $\frac{B.T.U.}{HR.\ FT.^2\ ^\circ F.}$
$\rho = \frac{A}{kR_T\left(\frac{2{\cdot}42\ \mu c}{k}\right)^{1/3}}$

$$Re=\frac{G_T}{2\cdot42\mu R_T}=\frac{W_T C_T k_o}{2\cdot42\mu R_T}$$

where

$$\frac{1}{C_T k_o}$$

is a flow area/tube pass.

$$\Delta P_T=\frac{N_T}{\gamma 10^{10}}W_T^2 C_T^2 k_o^2\left[Lf\left(\frac{W_T C_T k_o}{2\cdot42\mu R_T}\right)+0\cdot6\right]$$

$$=zC_T^2[Lf(B_1\times C_T)+0\cdot6] \quad . \quad . \quad . \quad (11)$$

where z and β_1 are constants for a particular fluid.

Tube-Side Heat Transfer

See equation (7).

$$h_T=J_H\frac{k}{D}\left(\frac{2\cdot42\mu c}{k}\right)^{\frac{1}{3}}.$$

The equivalent area for heat flow on the outside of tubes is diminished by the ratio of

$$\frac{\text{O/D tube}}{\text{I/D tube}}$$

Hence, tube-side resistance to heat flow,

$$S_T=\frac{1000\dfrac{\text{O.D. Tube}}{\text{I.D. Tube}}}{h_T}=\frac{A}{h_T}$$

$$=\left[\frac{A}{R_T k\left(\dfrac{2\cdot42\mu c}{k}\right)^{\frac{1}{3}}}\right]\frac{1}{f(\beta_1\times C_T)}=\frac{f(\beta_1\times C_T}{\rho}$$

$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

where ρ and β_1 are constants for a particular fluid and C_T could be plotted against standardised heat exchangers.

Example

Physical properties of the fluids are given below.

Units	Tube side	Shell side
Q—Heat duty, B.Th.U./hour	$3\cdot9\ 10^6$	$3\cdot9\ 10^6$
ΔP—Press. drop per square inch	1	1
Inlet temperature, deg. Fah.	250	100
Outlet temperature, deg. Fah.	200	130
W—Fluid flow, pounds per hour	$2\cdot17\ 10^4$	10^4
μ—Viscosity centipoise	·6	·245
c—Specific heat	·69	·9
k—Thermal conductivity $\frac{\text{B.Th.U. feet}}{\text{hours feet}^2\text{ deg. Fah.}}$	·886	·402
γ—Specific gravity	·8	·0962
Fouling factor $\frac{\text{Hours feet}^2\text{ deg. Fah.}}{\text{B.Th.U.}}$	·002	·001
Tube metal heat resistance $\frac{\text{Hours feet}^2\text{ deg. Fah.}}{\text{B.Th.U.}}$	·00015	

For practical considerations, the following tubes were taken: 1in diameter, 16 S.W.G. on 1¼in square pitch, 8ft long and $N_T=2$.

Using the above data, we get:

$\Delta T=110$ deg. Fah. $\quad De=\cdot0825$ft
$\rho=100$ $\quad R_T=13\cdot8\text{ft}^{-1}$
$z=10^{-3}$ $\quad C^1=\cdot25$in
$\rho_1=400$ $\quad k_o=\cdot921$
$\beta_1=10^3$ $\quad A=1150$
$\delta_1=10^6$
$z_o=10^5$ $\quad A_1=4\cdot19\text{ft}^2$.

Assume $C_T=10\text{ft}^{-2}$, which corresponds to

$$\frac{1}{C_t k_o}=\frac{1}{10\times\cdot921}=\cdot1085\text{ square feet}$$

(actual tube flow area).

Then, using appropriate value of β_1, tube diameter, tube length and z, as shown in the graph, Pressure Drop, Tube Side, we get:

$\Delta P_T=0\cdot124$ per square inch < allowable pressure drop.

By similar procedure heat resistance on tube side (as shown on the graph, Heat Transfer Tube Side) is

$S_T=2\cdot4$.

Now, assuming $d_s=8$in, $B=3$in and $N_s=1$,

$\Delta P_T=\cdot745$ per square inch < allowable pressure drop

$S_s=3\cdot2$, from graph Heat Transfer Shell Side.

S, total resistance to heat flow
$=(S_T+S_S)+(f_s+f_t+M)$
$=(2\cdot3+3\cdot2)+1000\ (\cdot001+\cdot002+\cdot00015)$
$=8\cdot75$.

E was taken from TEMA standards.
$E=\cdot98$.

Heating area required:

$$A_o=\frac{QS}{1000(E\Delta T)}=31\cdot6\text{ft}^2.$$

Actual heating surface $=4\cdot19\times7\cdot65=32\text{ft}^2$.
Assumed effective tube length $=7\cdot65$ft.

Acknowledgments

Co-operation of the management of Head Wrightson Processes Ltd., in the release of this information and assistance in its compilation is gratefully acknowledged.

The Training of Industrial Process Workers*

OPERATING EXPERIMENTAL RIGS

By M. J. ALLDAY, A.M.I.Mech.E.†

In the early years of the Research and Development Laboratories of the U.K.A.E.A. at Capenhurst, it was necessary to operate a variety of large experimental rigs, to meet development requirements of the diffusion plant. Rig operation is far from routine work, but a programme of training industrial process workers for such work was introduced, to avoid employing large numbers of professional staff. The first training scheme was mainly empirical, and did not achieve a marked success, although associated measures of standardisation of design, construction and operation of rigs proved to be very valuable. A fuller training scheme was evolved after detailed study of the work and of the men themselves. Rig work was analysed into its constituent steps, and lectures were given on fundamental scientific principles relevant to these. The lectures were supplemented by individual examinations of the workers, and the scheme was enlivened by friendly competition between shifts. The scheme achieved its objects of training process workers, not necessarily having a technical background, to operate rigs confidently with little supervision, and to produce accurate recorded information. To be fully effective, training must be continuous, maintaining knowledge up to date.

THE Research and Development Laboratories at Capenhurst are now a part of the Development and Engineering Group of the U.K. Atomic Energy Authority. They were set up in 1951, with a nucleus of staff moved from Springfields, where experimental rig work had previously been done. The laboratories deal with diverse problems in a wide technical field, and engineering work has always been a major part of their activities; in the early days most of the effort of the Laboratories concerned problems of the gaseous diffusion plant, examined on behalf of the Diffusion Plant Design Office at Risley, the headquarters of what was then the Industrial Group of the Authority. A special feature of the development work at Capenhurst has always been that experiments can be mounted on different scales ranging up to that of full-size machinery—actual items of production plant can be run in rigs, which are large pieces of apparatus instrumented or adapted to give results on specific aspects of operation.

Until June, 1952, rig work was under the direct supervision of professional engineers, each being responsible for the whole of a job, that is, designing a rig, building it and running it. This system was wasteful of effort: for instance fitters would be fully employed during building but not during operation of a rig, while the industrial labour assigned to rig operation would similarly not be fully employed during building.

In June, 1952, the Engineering Section of the Laboratories was re-organised by dividing it into four smaller units. These were the Construction Group, responsible for building rigs; Services Group, which provided general and electrical services, instrumentation, &c; Operations Group, which ran the rigs; and Operational Development Group, responsible for scheduling work and analysing the results of rig experiments.

Thus the Operations Group became responsible for running different types of test rig for diffusion-plant development. This presented a serious problem, since the available labour force of "process workers" had been recruited from different walks of life, and had no experience or training in work on development rigs, the operation of which would be far from routine, and under the charge of non-technical foremen.

The problem of using the labour force to best advantage was solved by a programme of imparting the basic knowledge needed for understanding rig operation to the process workers, and training them to apply it. Standardisation of operating methods and of the design and construction of the rigs proved to be a valuable aid to training. This paper describes the evolution of the training scheme and some of the results achieved, together with the measures of standardisation introduced.

Without such training in the early days, the Laboratories would not have been able to

* Contributed by the United Kingdom Atomic Energy Authority (Development and Engineering Group), Research and Development Branch, Capenhurst, Chester.

† Mr. Allday is now at the Royal Ordnance Factory, Radway Green, Crewe.

Technical Contributors Section (*continued*)

fulfil the heavy programme of development work to which they were committed. The only alternative would have been to employ large numbers of professional staff, of which there was, and still is, a shortage. As the result of training, process workers in the Laboratories now perform work which differs fundamentally from routine production work in that the modes of operation, methods of experimental procedure and even the rigs themselves are in an almost continuous state of modification, apart from standardised basic operations. The process workers have to be completely mobile in their duties, and ready to take charge of new and unfamiliar development equipment at short notice.

The training scheme described in this article was devised and run entirely by Research and Development Branch, Capenhurst. Although it is a number of years since its conception, it is thought that an account of it will still present many points of interest.

The Extent of the Problem

When the Operations Group of the Engineering Section was formed in June, 1952, only eight rigs had been built, for development of components for vertical compressors. Not more than four were operated at any time, the remainder being in the hands of other Groups for construction or inspection work. Operations on the rigs were conducted personally by qualified shift engineers. The tasks of process workers consisted of opening and closing valves when told, recording readings of instruments at pre-arranged times, and keeping traps chilled with coolant. With untrained labour, even these relatively simple operations had to be checked.

By the end of 1952 nineteen other rigs had been built, for developing components for new compressors. It was planned that, by January, 1953, twelve rigs would be running simultaneously—a threefold increase in operating work. Moreover, the work would be more complicated, since the rigs were for different sizes of motor and were themselves of three types (stage, mechanical and gland test rigs). A shift engineer could not physically operate all these rigs himself. The work of the Group had to be re-organised so that process workers could operate rigs. This was the prime object of the training scheme.

The Extent of Training

Details of the two training schemes introduced are given in the following Sections, but it is interesting to survey broadly the extent of training given.

Between June, 1952, and April, 1954, process workers spent 12,000 man-hours in training for operating test rigs. This is equivalent to the effort spent in running a stage test rig continuously for 5½ months. Two-thirds of the time was spent between May and October, 1953, when training was given some priority. In those six months, training accounted for 7½ per cent of the total time of process workers.

The First Training Scheme

The Empirical Attack.—Initially, training took the form of telling process workers how to do each operation as it occurred. The shift engineer would decide what operation was needed on a particular rig, tell the process worker how to do it, and leave him. He would do this on all the working rigs in turn, returning to the first to check that the first operation had been done correctly, and so on.

This method was very slow, for several reasons. By the time a process worker had been told how to do four or five operations, he might well have forgotten how to do the first. If a run ended on a particular rig, the process worker would be transferred to another, where different operations might have to be explained from the beginning. Different shift engineers were found to have different operating procedures, and this added to the number of things which had to be learned empirically.

Standardisation of Rigs.—As new rigs were brought into use, it became clear that some measures of standardisation between them would reduce confusion and help both in training workers and in operation. These measures included the design, construction and operation of rigs.

The design of rigs was standardised by treating them, wherever possible, as four systems. The main system, the "main plant circuit," included the compressor, cooler, membrane, control valve and connecting pipes. The other three were ancillary systems: the "nitrogen feed system," "hex feed system" and "fluorinating system." Each system could be isolated from the others, and had its own vacuum-testing unit.

Flow diagrams for rigs were also standardised, so that each of the four systems had the same symbol and the same pattern of pipework on all rig diagrams. The systems were drawn in the same position, e.g. the main plant circuit in the centre and the nitrogen feed system in the top left-hand corner. Valves and instruments which served the same purpose were given the same names and identification numbers.

It was difficult to standardise rig construction because of restrictions of space; this can be appreciated from Fig. 1, a view of the main experimental hall. Ancillary systems could not be in corresponding positions in all rigs. Nevertheless, such things as the position of pipework and the location of valves and instruments could be made standard, and so the different systems could be readily distinguished. Electrical switch panels were also made similar. These items of standardisation, and the use of standard operating methods (described in the next Sub-section), brought many advantages to training. Once process workers learn to read one flow diagram and to operate one rig, they find it easier to deal with other diagrams and rigs, particularly if they have standard features. They soon appreciate that some operations can be done in the same way on different rigs.

Standardisation of Procedures.—A further measure of standardisation was to write "Operational Procedures" and "Operational Notes" for all operations which recurred during rig work. These helped process workers to know precisely what to do and why they were doing it. As an example, the minor operation of charging the nitrogen buffer vessel on vertical stage test rigs—frequently repeated during different runs—was suitable for such procedures and notes to be written.

The "Operational Notes" began with an explanation of why the vessel was included in the rig system, and the pressure to be maintained. The operation of charging was then set out in six steps, from

(1) Check that the buffer vessel is within the pressure variation allowed,

through to

(6) Close nitrogen mains valve. Close the valves between the control valve and buffer vessel and between the control valve and nitrogen main, taking care not to close the outlet valve on the buffer vessel.

Against these steps were given the reasons for doing them—thus "This isolates nitrogen main from the plant" against step (6).

The corresponding "Operational Procedure" was much shorter, simply listing the

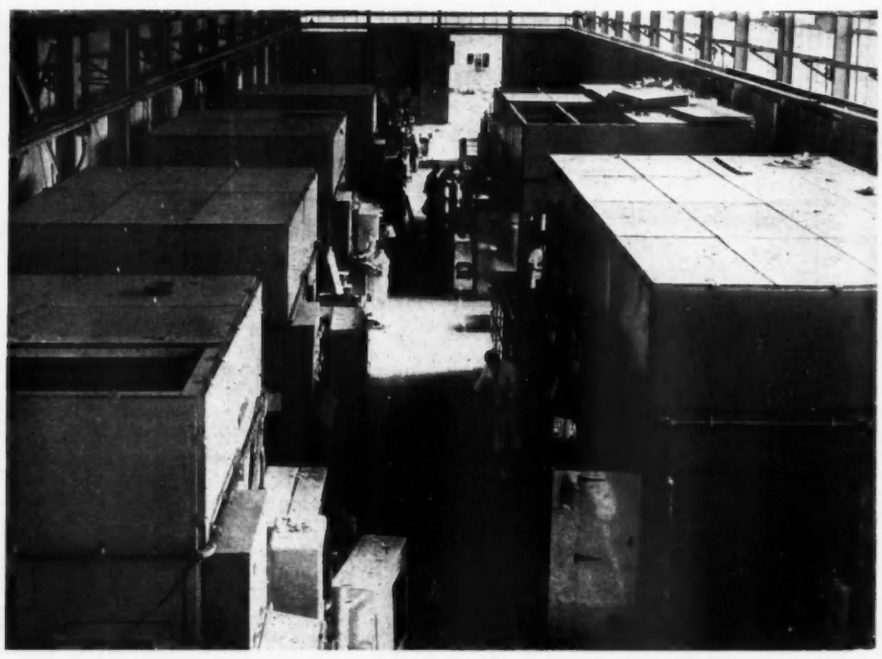


Fig. 1—R. and D. Branch, Capenhurst : engineering rigs in the main experimental hall

actions needed for all steps explained in the "Notes." Thus the two steps already given appeared as

(1) Check pressure. Take reading on gauges P14 and P21: if pressures are not within 5mm, report to chargehand.

(6) Close valves. Close valves 78, 77 and 50.

Such standardisation of operating methods was extremely valuable. It encountered difficulties, such as operational procedures becoming out of date by the time they were issued, because of modifications to equipment or the introduction of new ways of performing operations. Such difficulties, however, are inherent in research and development work.

Results of the First Training Scheme.—Although standardisation brought many advantages, this initial scheme was not a complete success. Operating was slow, mistakes occurred, and test data coming from the rigs were not always as reliable as they should have been. These shortcomings arose from the method of training, which relied on process workers simply remembering by rote how to do several different operations. The poor results showed that a more fundamental and far-reaching programme was needed.

The Extended Training Scheme

In a more determined effort to eliminate inefficient operation of rigs, training was completely re-organised. The new basis was not just to rely on memory, but to give the process worker the basic knowledge from which he could think out for himself the way operations should be done. To plan this training, the entire work of the section had to be analysed, so that the amount of basic information needed could be assessed. The frequency of occurrence of each operation had to be found, to determine the relative importance of items to be taught. Moreover, the capabilities of the workers themselves had to be assessed, to discover the value of their existing knowledge and experience, and the best way of presenting the training programme.

Work Analysis—Division of Jobs.—The initial division of work is simple—work on a test rig consists of preparing it for a test, doing the test, and finally closing down. Each of these phases consists of major operations, such as fluorinating the plant, purging it, and preparing and starting the compressor. There were nine basic major operations. These operations, however, are not always identical. Fluorination varies according to the method used. Purging is different after fluorination from after withdrawal of hex or a failure of a seal. A compressor may be prepared and started in eleven different ways, depending on its type and the type of seal used. These differences brought the number of major operations to twenty-three.

Each major operation comprises minor operations, such as charging a nitrogen buffer vessel or admitting fluorine to a plant. Some minor operations are found in two or more major operations. The total number of minor operations was sixty. The further division of minor operations is into a series of steps, and by considering each step singly, the basic knowledge needed for it becomes clear. For instance, in recording a pressure, the process worker must know what is meant by pressure; the units used; the pressure-measuring instrument, and how to read this accurately; and finally, the recording system. In such ways the list of basic information was compiled.

The Operational Procedures and Notes, mentioned in the last Section, are step-by-step analyses of minor operations.

Work Analysis—Frequency of Operations.—The main object of the training scheme was proper operation of test rigs. Thus it was more important to stress information which was needed often, even if it was simple, than to dwell on more complicated but little-needed items of information. Hence the frequency of occurrence of operations had to be analysed.

It was assumed that eight rigs, representing all types in use, were operated continuously for twenty-four hours; this number was taken from planned requirements. The analysis gave interesting results, some of which are quoted here. In a 24-hour period :

(*a*) Some 2810 instrument readings were recorded—nearly two per minute. Fifteen per cent were plotted on graphs.

(*b*) Five complete changes of hex (uranium hexafluoride) were made. These involved withdrawal of hex from a rig, purification, sampling, gassing it to a buffer vessel, and admitting it to a rig.

(*c*) Rig samples of hex were examined for impurity eighty-four times, using either of two methods.

(*d*) Rig pressures were reduced thirty-eight times to keep them within set limits.

(*e*) Eighty pages of log books were used for recording.

(*f*) Beads on flow diagrams were moved so often that they had to be checked after each shift. This implied twenty-four flow-diagram checks, involving checking 2100 valves (open or closed), 168 switches (on or off) and 120 vacuum pumps (running or isolated).

This analysis gave a good indication of the work of the section, how often information was needed, and how thoroughly it was to be taught.

The Labour Force.—To decide on the best way of presenting training material, where to start and what methods to use, the background of the process workers themselves had to be examined.

All the workers had been through an induction course on entering Capenhurst Works. Nevertheless, it soon became clear that their knowledge, although sufficient for routine production work, would not fit them for dealing with the more complicated and specialised problems of operating development rigs, which by their very nature do not perform routine work. A probable cause of this insufficient knowledge was lack of previous technical experience. For instance, one worker thought that an evacuated system would collapse if a leak into it was not maintained, and another thought that the temperature of a rig depended on the environmental temperature in which a man can work. The previous training scheme on test rigs was of little value as a foundation. With the expansion of the work, more than half the men were new when serious training began. The others had spent on average two months in operating rigs, but the only real knowledge gained by most was the ability to name items of equipment.

The men's backgrounds showed that, of the ninety-two employed on rigs, only seven had had previous experience of process industry. Eleven of the more ambitious, however, had been in skilled occupations and had moved to atomic energy because chances of promotion seemed better. Fourteen clerical workers were potentially useful for handling the large volume of recorded readings and log books. Most of the remaining fifty-five men had been in semi-skilled occupations, only five having been labourers. An important fact was that one in five of the men had shown initiative in some way. For example, two had been warrant officers in the Army, one a foreman tailor and another a foreman baker; one had managed a tailor's shop and several had run their own small businesses. In many cases promising careers had been interrupted by the war. The educational standards of the workers were better than might have been expected. About a quarter had had an education which was better than elementary—one had been to a public school, four to grammar schools and one to a technical school. Only one had had an education below elementary standard.

This study of the workers gave grounds for optimism in starting the training scheme. Ambition and initiative indicated that training material could be absorbed so long as lectures were planned without assuming a technical background. The only apparent difficulty was that the average age was thirty-seven years, not an age at which many people readily participate in further education.

The Training Scheme.—The scheme was planned on the basis of the work analysis and the study of the process workers. Material to be taught was arranged in thirty-eight lecture subjects, comprising three groups. The first group dealt with fundamental information needed to understand the work, starting with elementary subjects like "Pressure and Temperature" and "Vacuum Techniques." The second group covered routine work which could be standardised, *e.g.* "Recording Instrument Readings." The third, and main, group was concerned with plant components; types of compressors, seals and rigs; operating techniques needed to produce experimental results from different rigs; and trapping and other auxiliary operations.

This was a wide syllabus, and it was appreciated that co-operation would have to be forthcoming from everybody for the scheme to be successful. As it was impossible to offer direct incentives of more pay or the promise of promotion simply on the results of training, the element of competition was introduced. To avoid possible ill-feeling between individuals, the shift was used as the unit, and each worked in competition with the other three. A "Training Progress Chart," such as is shown in Fig. 2, was prominently displayed. This was a simple device, similar to charts used for savings campaigns or production targets, and its columns were shaded to show increases in proficiency as training progressed, thus stimulating competition between the shifts.

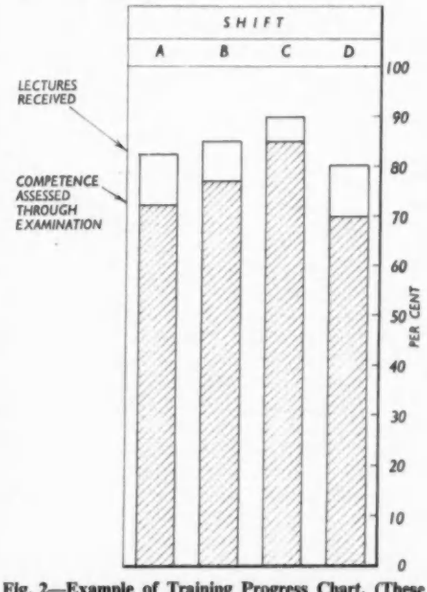


Fig. 2—Example of Training Progress Chart. (These charts were prominently displayed at poster size, and were kept up to date continuously)

Technical Contributors Section *(continued)*

Fig. 3—R. and D. Branch, Capenhurst : diffusion-plant rigs operated by process workers

The effect of the lectures was estimated by examining the process workers orally, in private, after each one. This gave an opportunity for the trainees to ask questions and for the examiners to clarify points which had not been understood. It also enabled the examiners to assess the workers and their suitability for various jobs, and to decide whether they would gain by attending a lecture a second or even a third time.

The times and staff for training were decided according to local conditions. The shift labour strength was based on the work required during the day, the busiest period when various tests outside the normal schedule and more difficult operations like fluorination and starting-up were done. There was thus a surplus of labour during the silent hours, and these men were available for training. Lectures were given by the shift engineers and foremen, using an office equipped with a blackboard, diagrams of plant components and specimens of valves and instruments which could be dismounted for inspection. So that the competition plan should not be biased, the examinations were conducted by one of the day staff of the Engineering Section.

How the Scheme Worked.—Lectures were given and received very well. The process workers were keenly interested and eager for knowledge.

At first the shift foremen, and to a lesser extent the shift engineers, showed some reluctance to lecture on subjects on which they felt they were not completely expert. To assist them and to ensure uniformity, lecture "breakdowns" were prepared on each subject; these showed the purpose of the lecture and which things were to be included or specially stressed. Lectures on matters which were to be standardised were written in full. Lecturing proved to be valuable experience for the shift supervisors, who thereby increased their own knowledge considerably.

The competition plan worked far better than had been expected. Competition among shifts was intense, and the process workers allowed the shift supervisors no respite from lecturing. The examinations were no deterrent from climbing the proficiency scale, and the training progress chart was never stable. Without the incentive which it gave, training would never have been accomplished so quickly.

The examinations were also very successful. Most process workers soon overcame their initial nervousness of being questioned, and welcomed the chance to ask questions and show their willingness to learn. A minority were unco-operative, for instance thinking that the extra work involved was unjust; these were later transferred to other sections. Some workers excelled, and were remembered with a view to promotion. One interesting fact which emerged from examinations where instruments had to be read was a general poor standard of eyesight. Many capable men gave inaccurate readings of barometers, manometers, &c.

The Results of Training

The training scheme was certainly successful, but in some ways fell short of what should have been possible, mainly through lack of thoroughness. Some curtailment of the scheme was necessary when a programme of reactor development was added to diffusion plant work at Capenhurst; thus those who would have benefited from attending a lecture more than once were not always able to do so. Staff changes meant that the essential revision or follow-up of training was not so thorough as desired.

Apart from these shortcomings, the object of the scheme was achieved. Process workers now do work which originally was done by shift engineers. They do all operations without detailed supervision, and deal with major jobs like fluorinations and emergency shut-downs with complete confidence and skill. They can produce accurate experimental information if instructed properly and given time to exercise care. The average process worker can be trained to be a competent rig operator.

Fig. 3 shows a typical rig for diffusion-plant work, operated by process workers.

Some Observations and Conclusions

Untrained process workers often make mistakes; they may show little interest in their jobs and need constant supervision. Trained process workers, on the other hand, make few mistakes and work accurately, provided that they receive proper instructions and do not have to "beat the clock"; they can work without constant supervision.

To maintain interest in the work, training must be continuous and knowledge must be kept up to date. To be thorough, training must not be rushed, and to be most effective it must be planned from work analysis.

Standardisation is essential when unqualified labour is employed. It should be used with simple things like naming and numbering plant equipment as well as more important things like plant construction and operating methods.

Allied with this is the need for things which are different to have distinguishing features. Instruments which look alike but have different scales always cause confusion and are often read wrongly. Vacuum and absolute-pressure gauges have zero readings of 760mm on the one and 0mm on the other, with the reverse for the atmospheric-pressure readings; these two gauges should never be used together. Likewise gauges which look similar except for the scale range and division should be distinctly marked.

When instructions are given to process workers, the important factors must be stressed. If time is not important, it should not be mentioned. Without guidance as to the relative importance of, say, time and accuracy, process workers may either spend a very long time doing everything accurately or do everything quickly and haphazardly.

Like most people, process workers respond to praise, often by raising the standard of their work and unconsciously trying to maintain that level. If mistakes are made, the supervisor must share the blame, and should be told about them before the person in error.

Safety must be remembered continually during training. Process workers showed surprisingly little respect for personal safety, and safety training must be reinforced by strict discipline.

Process workers can play an important part in releasing professional staff for more important duties, provided that they are properly trained and given the opportunity to do responsible work, and that confidence is shown in their abilities.

Acknowledgments

Mr. K. E. Jermy, Technical Editor at Research and Development Branch, Capenhurst, was responsible for preparing this article for publication. It is published with the permission of Sir William Cook, Managing Director, and Dr. H. Kronberger, Director of Research and Development, of the United Kingdom Atomic Energy Authority (Development and Engineering Group).

Progress of the Metropolitan Water Board's New Works

A brief account is given of the progress made during 1960 with the various new works under construction for water supply in the London area.

FOR the Metropolitan Water Board, the main event of engineering significance in 1960 was the inauguration of the Thames to Lee Valley raw water tunnel on September 28 last. The scheme was described in our issue of October 7, 1960, but we show in the heading illustration the outdoor pumping station, at the terminal shaft close to Lockwood reservoir in Walthamstow, of the 19 mile tunnel of the scheme.

There are two groups of three vertical-spindle bore-hole pump sets at this station. The first group draws water from the shaft, which is approximately 70ft deep and 25ft in diameter, and pumps it through a 54in main to High Maynard reservoir. The second group delivers through a 54in main to Chingford South pumping station or to Lockwood and Banbury reservoirs. One pump is cross-connected.

All the sets are controlled from Ferry Lane pumping station, ½ mile distant, and deliver to mains through 18in Harland-Morgan Smith "Rotovalves," electrically controlled and hydraulically operated and each capable of operating against an unbalanced head of 200ft, seven of which are installed, one being used in each of the branches of the cross-connected set. Delivery valves are automatically opened or closed. A seventh set of submersible type is installed for dewatering the tunnel and shaft.

Each bore-hole set is capable of delivering 25 m.g.d. The first group each have 350 h.p. squirrel-cage motors fully weatherproofed for outdoor operation, and supply against a total head of 48ft at 495 r.p.m. The pumps of the second group are each driven by weatherproofed 650 h.p. squirrel-cage motors at 740 r.p.m., and operate against a total head of 92ft. This is the first "outdoor" pumping station to be constructed by the Board, its equipment having been designed and constructed by the Harland Engineering Company, Ltd.

Walton South Reservoir

During 1960 progress with the construction of the Board's 4300 m.g. storage reservoir at Walton was maintained to schedule by the contractor, W. and C. French, Ltd. The clay core wall was completed and the embankment, which contains approximately 3,000,000 cubic yards of material, was brought up to its full height at 83·60 O.D. by the middle of July, 1960. In addition, a further 2,000,000 cubic yards of surplus material were excavated from within the reservoir and removed from the site. After completion of the embankment, the main effort was concentrated on lining the inner slope of the reservoir with 6in concrete slabbing, of which 100,000 super yards, which represents nearly 50 per cent of the total, were laid. A start was made in the autumn on the soiling and seeding of the outer slope of the embankment, but the excessively heavy rainfall in October caused this work to be suspended until next spring.

The inlet pierhead and the prestressed concrete bridge were completed. From this pierhead the valves controlling the inlet jets will be electrically operated. In addition to the inlet jets, there will be two 72in diameter conduits leading to the far side of the reservoir, and one of these was completed. The raw water which enters the reservoir through the inlet jets will be pumped from the Walton pumping station through a 100in diameter tunned which passes under the reservoir embankment about 140ft below the surface.

The outlet tower was completed during the year and a granite faced bridge connecting it to the embankment was two-thirds complete. The outlet tower is a "wet" tower and stands over a shaft on the 100in diameter outlet tunnel which will take the water under the reservoir embankment to connect with mains leading to the Board's filtration works at Walton, Hampton and Surbiton. The water in the reservoir will be drawn into the tower through penstocks at four different levels and also from a 72in diameter conduit which will lead into the tower from the centre of the reservoir.

Staines to Kempton Tunnel

In the autumn a contract was let to Edmund Nuttall, Sons and Co. (London), Ltd., for sinking five shafts and driving a 100in internal diameter tunnel about 4¾ miles long, so that additional raw water can be conveyed from the Staines and Queen Mary reservoirs to the Kempton Park and Hampton Works and also to the new filtration works at Ashford Common. The tunnel will be lined with "wedge block" precast concrete slabs. At Staines the top soil was removed from the area provided for the contractor's operations and the construction of a concrete block casting shed was nearly completed. This site factory will be used for the manufacture of some 150,000 segments required for the tunnel lining. The top soil was also removed and a temporary concrete road was constructed around the site for the Ashford Common shaft. Concrete piles were being driven into the clay around the shaft site.

Augmentation of Supply to the Kent Area

The general outline of the scheme was given in the review published at this time in 1958. Erection of the additional pumping plant at Horton Kirby was completed in 1959 and at Lullingstone in 1960. Erection of the new pumping plant was in progress at Shortlands and Sundridge, and the new machinery was delivered to North Orpington. Bore-hole sinking was completed at Sundridge to a final depth of 195ft. The mains for the improvement of the supply were laid, apart from the 270 yards of 21in steel main at Catford Bridge. The 5 m.g. service reservoir at Farningham was constructed and tested for watertightness.

Good progress was made on the further stage of the scheme which comprised the construction of a 5 m.g. service reservoir at Farnborough and the laying of 3910 yards of 12in main in Orpington. The mass concrete walls were constructed apart from an access bay, 75 per cent of the 8in top floor was placed, 55 per cent of the roof columns were erected and work was proceeding on the roof shuttering, the fixing of reinforcement and the placing of concrete on the roof. Some 2200 yards of 12in main were laid.

Improvement of the Supply to the Ditton Zone

The Board on October 23, 1959, approved an estimate of £628,000 for the improvement of the supply to the Ditton zone. This zone has an area of approximately 16¼ square miles and a population of about 125,000; it includes the entire Borough of Surbiton, an extensive part of Esher, part of Kingston, Epsom, Ewell, Malden and Coombe, and Sutton and Cheam and extends to the south of Chessington. In recent years the daily consumption in the area has increased considerably due to development, and in order to maintain a satisfactory supply at all times and to provide for future development it was decided to lay a number of interconnecting mains, construct a service reservoir with a capacity of approximately 4·5 m.g. at Telegraph Hill, Chessington, and lay a trunk main from Walton pumping station to the proposed new service reservoir. The total length of trunk main will be approximately 15,000 yards, 6000 yards of which will be 30in diameter and the remainder 24in diameter. During the year 2750 yards of 10in interconnecting mains were laid, and also 1915 yards of 30in and 5059 yards of 24in trunk main from Walton pumping station. A further contract has to be let in this year for laying the section of the trunk main from Hook Road, Surbiton to the new reservoir site.

Other Works

Work continued on a number of remodelling schemes. At Bexley a new pumping station was built to the stage for

the installation of machinery which is now being erected. At Darenth work commenced on the demolition of the old buildings and remodelling the boiler-house to form a new pumping station, and at East Ham and Southfleet pumping stations the remodelling schemes were substantially completed. Further progress was made on remodelling Walton pumping station: the new pumps and motors for units Nos. 8 and 9 were erected, the contract for the construction of supply section buildings and road works was 60 per cent completed, and work was proceeding on the remodelling of the existing pumping station.

Work by direct labour on the reconstruction of the slow sand filter beds at Hampton Works was continued. One further bed was reconstructed and half of the walls of another bed was completed.

Although not in the category of "new works" one other matter of engineering interest which was topical in 1960 was the discussion of results (in a paper at the I.C.E., see THE ENGINEER January 15, 1960, page 106) on a series of experiments on the artificial recharge of water-bearing strata in the Lee Valley.

All the new works discussed in this article are being constructed under the direction of the Metropolitan Water Board's chief engineer, Mr. W. M. Lloyd Roberts.

Welded Boilers and Pressure Vessels

A symposium on "Pressure Vessel Research Towards Better Design" was held in London last week by The Institution of Mechanical Engineers in co-operation with the British Welding Research Association. In one of the papers J. F. Lancaster, B.Eng., compared the laws governing the construction of welded boilers and pressure vessels in a number of European, Commonwealth and North American countries. On the basis of this comparison the author appraised possible future lines of development of British codes. He explained that his paper represented the position in 1960. Thus, because of their provisional nature, two proposed codes were not considered in detail, although they may influence European codes, particularly by encouraging the adoption of yield point instead of ultimate tensile strength as a criterion of design stress. These provisional codes are the INSTA code, which is a recommendation for a common basis for the development of national standards in Denmark, Finland, Norway and Sweden, and the I.S.O. boiler code which is only in draft form. Extracts from the paper are reproduced below. We also give* in extenso *the paper on "Pressure Vessel Design Requirements in the Near Future" by W. B. Carlson†*

A COMPARISON OF UNITED STATES, EUROPEAN AND BRITISH COMMONWEALTH CODES FOR THE CONSTRUCTION OF WELDED BOILERS AND PRESSURE VESSELS

Laws and Governmental Regulations

BECAUSE of the inherent hazard involved in their use, the construction of boilers and pressure vessels is subject to regulation by a Government department in most of the countries surveyed.‡ The degree of legal control varies a great deal; on the one hand there are countries such as Italy and Austria where rules for construction are set out in detail in a ministerial decree and others, such as India and New Zealand, where the code is written and issued by a Government department, and is, in fact, a ministry regulation. At the opposite extreme, in the United Kingdom of Great Britain the law gives the very minimum of guidance as to means of construction. Other countries, such as the United States of America, Canada, and Australia have adopted a method of regulation which lies between these two extremes; the Government or local authorities give approval to a code which is written by a body of professional engineers, thereby vesting this independent code with the authority of law.

The administration of boiler and pressure vessel codes varies to a like degree. In the majority of countries there exists an inspectorate whose duty it is to give rulings on the interpretation of the code, which approves drawings and which carries out physical checks during construction. In many cases this inspectorate is part of a Government department (Australia, Canada, India, New Zealand, Pakistan) whilst in others there is a Government-approved inspection agency that performs this function (Germany, Italy, Norway, Sweden, Switzerland). In the United States of America, states and municipalities which have adopted the American Society of Mechanical Engineers (A.S.M.E.) Code supervise construction broadly through their inspectorate, but checking of drawings and detailed inspection is carried out by an authorised A.S.M.E. inspector. In Britain on the other hand, there is no Government or Government-approved inspectorate responsible for supervising boiler and pressure vessel construction, inspection being carried out by purchasers, by Lloyd's, by the Associated Offices Technical Committee (A.O.T.C.) or other inspecting bodies.

Thus there is a wide variation in the degree of legal authority given to construction codes and the degree of governmental inspection of boiler and pressure vessel manufacture in the countries examined, ranging from virtually no control, as in the United Kingdom, to the very close official supervision of the content of the code and of all phases of construction which is achieved in many European countries. Experience suggests, however, that standards of safety achieved in these various countries are almost uniformly high; failures of welded pressure vessels are rare and when they occur are not normally associated with inadequate wall thickness or deviations from the normal standard of construction. In fact, this desirable situation results more from a combination of sound engineering practice with commercial integrity than from any form of legal compulsion. Although regulations differ widely, drawing-office methods and quality control procedures are broadly similar, and where there is no supervision from Government inspectors, this supervision is, nevertheless, supplied by the manufacturer, a classification society, by the purchaser, or in some other way.

Material Specifications

Table I lists the range of material specifications associated with the various codes and gives some indication of their range of application so far as materials are concerned. Needless to say the A.S.M.E. Code lists by far the greatest number of specifications, corresponding with the detailed character of this code and its great breadth of application.

In the specified requirements for carbon steel boiler plate there is good general agreement as regards the specified tensile properties. There is, however, considerable variation in the degree of control over chemical composition, the Swedish specification being the most detailed, whilst, on the other hand, the Swiss Code contains no requirements for chemical composition whatsoever. A model of compactness is to be found in the German Standard DIN 17155, which lists the available carbon and low-alloy boiler plate steels together with their mechanical properties at elevated temperature. This type of specification is of real value to the designer, who can obtain from it a clear definition of the properties of the material which he is specifying.

Estimates of the elevated temperature properties of steels given, in specifications or implied in the permissible design stresses listed in the codes, vary quite considerably. In general, Continental European codes tend to be more conservative than the A.S.M.E. Code in the design stresses permitted for carbon steel in the creep range; in particular the German figures for carbon steel at temperatures over 650 deg. Fah. (which are backed by a substantial research effort) are decidedly lower than the American figures, although results for comparable alloy steels are similar. This discrepancy gives rise to some uncertainty when, for example, a vessel to be used at elevated temperature is designed to the A.S.M.E. Code using German steel, and it emphasises the need for the further extension of knowledge of the creep properties of standard carbon steels.

There is a significant difference between the maximum carbon contents specified for Continental European steels and those specified for American steels, both in the carbon and low-alloy range. The actual difference between carbon contents of boiler plate steels used in Europe and the United States

TABLE I—*Material Specifications Listed by Pressure Vessel Codes*

Country	Number	Carbon steel	Cast iron	Low alloy steel	High alloy steel	Copper	Copper alloys	Aluminium	Aluminium alloys	Nickel	Nickel alloys
United Kingdom A.O.T.C. Rules	1										
Switzerland	8										
Finland	10										
United Kingdom Lloyd's Rules	13										
Austria	16										
Italy	18										
Australia	22										
Sweden	22										
Holland	31										
New Zealand	54										
United Kingdom B.S. 1500	62										
Germany	91										
France (S.N.C.T. Code)	97										
United States of America	600										

* Kellogg International Corporation, London.
† Babcock and Wilcox Ltd., London.
‡ Details were given in a table in the paper.

is, perhaps, not so great as would be suggested by the specification figures. Nevertheless, there is, in the broadest sense, a tendency for the acceptable carbon content of steel to be higher in the United States than in European practice, and this tendency is reflected in the specification figures.

Steels for use at sub-zero temperature in chemical process plants are specified in A.S.T.M., British, and German (V.D.Eh.) standards, but guidance as to their use is to be found only in the A.S.M.E. Code and in B.S. 1500.

A problem peculiar to Britain (and deriving in part from the multiplicity of British codes) is the multiplicity of specifications for boiler and pressure vessel plate. B.S. 14, an old specification, originally designating plate for riveted marine boilers, still finds wide use for welded pressure vessels, although it sets a quality standard below that normally required in current engineering practice, and competes in a most undesirable way with the other two standards, B.S. 1633 and B.S. 1501–151. It is inevitable that a lower-quality standard should tend to persist, and action to define and specify the quality level required for a British standard boiler plate, applicable equally to pressure vessels, is urgently required. If it is found that more than one quality level is required, then their permissible conditions of use should be accurately defined in the code.

Fabrication and Inspection

The majority of codes pay special attention to welding ; in particular the A.S.M.E., the Australian and the Swedish codes have a separate section devoted to the application and control of welding. In Europe it is normal to require tests plates to be welded with longitudinal seams ; this constitutes the most common form of quality control over welding. In addition, some countries require welding operators to be individually qualified and Australia, New Zealand, Sweden, Switzerland, and Lloyd's of Britain require separate approval of the works in which welded fabrication is carried out. In the United States and Canada, on the other hand, the welding procedure and welding operators must be qualified but routine tests taken with longitudinal seams are not mandatory.

The alternative systems of routine testing or welding procedure and operator-qualification testing both have merits and demerits. Routine testing gives a continuous check on the quality of weld metal deposited, but it is costly and scarcely justified for carbon steel vessels of normal thickness welded using standard procedures. Procedure testing ensures that a proper welding technique is established before production work starts, but does not give any check on subsequent deviations ; it is, in fact, an aid to production rather than a quality control measure. On balance, the interests of safety in use are best served by routine testing, relaxed for experienced fabricators in the case of the common run of carbon steel vessels. The combination of operator qualification and works approval with routine testing seems unnecessary since routine tests in themselves constitute a check on both operators and works equipment.

Radiography is the only non-destructive testing technique generally recognised for welds, and it is common practice to give credit in terms of increased allowable joint efficiency in the case of vessels subject to radiographic control. A further credit is given for stress relieving and for other fabrication procedures in accordance with the quality level which is thereby achieved.

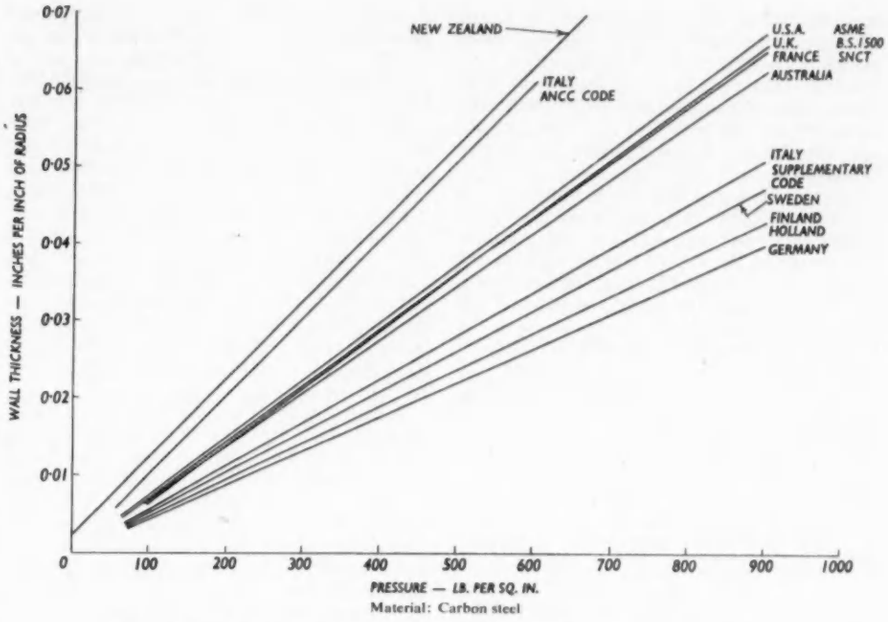


Fig. 1—Wall thickness of welded cylindrical shell subject to internal pressure

In general, the codes surveyed are deficient in that, although they indicate different levels of quality of fabrication, little or no guidance is given to designers as to the services for which the different quality levels should be specified. An exception is Lloyd's Rules which gives pressure and temperature limitations for each of the three classes of vessel. However, this code was not designed for, and does not consider, the needs of the modern petroleum, chemical, and petrochemical industries, for which the nature of the service, in particular the degree of hazard involved, must be taken into account in defining quality classes according to service.

Design

Joint efficiency factors have been tabulated for three levels of weld inspection, corresponding broadly to those specified by B.S. 1500 for vessels of Class I, II, and III respectively. With one or two exceptions, there is a fair measure of agreement as to the credit to be given for various degrees of inspection.

Fig. 1 shows the wall thickness of cylindrical carbon steel shells as a function of pressure. These curves have been constructed using the maximum joint efficiency factor permitted by the code in question, in combination with the basic design stress for the relevant steel. The wide variation between the wall thicknesses so derived stems mainly from variation of the basic permissible design stress. This is further illustrated in Fig. 2, which shows the variation of permissible stress with temperature, according to six of the codes.

The most immediately obvious division is between those countries which permit a design stress equal to two-thirds of the yield or proof stress (Holland, Germany, and the Scandinavian countries) and those which limit the design stress to one-quarter of the ultimate tensile stress (Britain, the British Commonwealth, France, the United States). Use of the former criterion leads to considerable economy in the use of material for carbon steel pressure shells as compared with the older system current in Britain and the United States. Such economies are even more pronounced when high-yield-point steels are employed.

At temperatures over about 650 deg. Fah., where the possibility of failure by creep limits design stress, the situation changes. The A.S.M.E. Code is decidedly less conservative than the remainder, and at a temperature of 900 deg. Fah. permits a

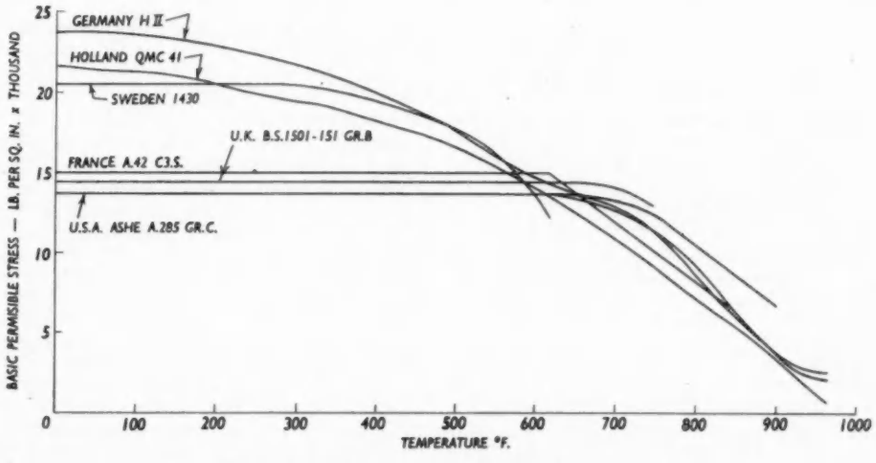


Fig. 2—Permissible stress as a function of temperature

working stress about twice that which is allowed by the German code. Indeed, when designing vessels to the AD-Merkblätter, it becomes economic to use alloy plate at a temperature substantially below the permitted limit for carbon steel, of 520 deg. Cent., whereas for the A.S.M.E. Code the reverse is the case.

The trend which has been noted in the case of cylindrical shells holds good also for dished ends, spheres, and conical sections. The design of flat covers and tube plates, on the other hand, does not lend itself to simple formulation, and for these components the calculated thickness varies not only with the basic design stress but also with the assumptions made in deriving and applying the design formulae. Tube plates, for example, may in some circumstances be thicker when designed in accordance with the AD-Merkblätter than when designed to T.E.M.A. standards.

The amount and character of design information given varies considerably. The Austrian and Swiss codes are limited to essentials. The Swedish and Dutch codes have both been rewritten in recent years and achieve a clear presentation of modern design techniques. The German code has, until just recently, lacked information about some essential matters (shells under external pressure, for example), and has lacked a clear statement of quality control requirements for welding, but these deficiencies are being remedied and the boiler code, Werkstoff and Bauvorschriften, is currently being revised and reissued under the title "Dampfkessel-Bestimmungen." The Commonwealth codes (except in the case of Canada, which accepts the A.S.M.E. Code) have been influenced by current British code and in particular Lloyd's Rules : the Australian code also has some affinities with the A.S.M.E. Code. The A.S.M.E. Code itself has a wider coverage of design than any of the other codes examined, although the presentation has suffered as a result of its growth.

Italy and Great Britain have the distinction of possessing a multiplicity of codes ; in Italy there are two and in Britain, three. The Italian codes have different (although not well defined) spheres of application, however, whereas in Britain the British Standard, Lloyd's, and A.O.T.C. codes all cover similar ground. Relative to other countries, this situation is unusual and possesses obvious disadvantages, and it would seem justified to consider, albeit briefly, in what way future development of the British codes might eliminate this and other deficiencies, bearing in mind the more recent development of the codes which have been surveyed.

Discussion

In considering codes and their developments, the first essential is to decide upon the essential functions of the boiler and pressure vessel construction code. Clearly one of these functions is to achieve safety in use. However, it may be questioned how far the existence of a detailed code is essential to this end. Some countries which are not lacking in technical resources, for example, Belgium and Israel, have neither code nor any detailed governmental supervision of construction, and yet achieve adequate standards of safety. In Great Britain there are a number of codes but no direct legal enforcement of their use and at the same time no evidence of lack of safety in operation. Therefore, although the content of a code must be such as to ensure safety, considerations of safety do not necessarily govern its line of development. Likewise there is no evidence for any need to provide direct legal authority for the code as far as operational safety is concerned.

On the other hand, there is a positive disadvantage of legal authority where the law is detailed in its requirements. The rapid development of both the industry using pressure vessels, and of the manufacturing side, requires that codes and material specifications should be flexible, capable of amendment to suit the needs of, on the one hand, wider spheres of use, and, on the other hand, greater economy in production, and such flexibility is impossible in legal enactments. Therefore, the objective should be to achieve conformity to safety standards by voluntary, collective action rather than by legal compulsion.

The second function of a code is standardisation. The industry manufacturing and using boilers and pressure vessels is a large one with wide ramifications, and it is self-evidently essential to have some degree of standardisation in the manufacture of its apparatus. Standardisation can reduce costs at all levels : at the design level by simplifying design procedures ; at the supply level by standardisation of the size and design of nozzles, manways, vessel ends and so forth; and in construction by minimising the need for independent detailed decisions by inspectors and by rationalising the procedure for accepting vessels.

So far as Great Britain is concerned, the chief obstacle at present to effective standardisation is the existence of three main codes applicable to boilers and pressure vessels, namely the British Standard Codes which include B.S. 1113 and B.S. 1500, Lloyd's Rules, and the A.O.T.C. Rules. The existence of these different codes in turn generates a multiplicity of material specifications, results in different standards being set for vessels having similar duties, adds to the amount of drawing-office work, reduces the possibility of standardisation in construction, and adds considerably to the burden of inspection. It would be an important step towards economy in the industry concerned if a unified code acceptable to all the authorities concerned could be developed in Britain.

A pressure vessel code also has an educational role to play. It is one of the means by which the accumulated experience of engineers in the industry concerned is set down for the benefit of younger men and in this sense it is an essential vehicle of instruction. The degree of success achieved in this field will depend upon the scope and engineering quality of the code and the degree to which it is capable of providing a straightforward solution to day-to-day problems commonly arising in industry. It is self-evident that in the educational sense the existence of more than one code is a potential source of confusion and makes it impossible for any of the codes to be truly authoritative,

A second defect in the existing British system (which once again derives from the existence of a number of codes) is the lack of a single body responsible for code administration. Codes must be administered at both the design stage and at the manufacturing stage if they are to be effective. There must be a body capable of giving uniform interpretation of cases not anticipated by the code, and an inspectorate capable of checking drawings, manufacturing procedures, and tests. Such an arrangement obtains in the great majority of the countries surveyed in this paper. In Great Britain its achievement would not be easy, owing to the manner in which codes have developed. However, it is only through such an organisation that a code can be given continuity and life, and its existence is essential if a British code is to act as an effective instrument for standardising and developing engineering practice in the field of boiler and pressure vessel construction.

Perhaps the most controversial issues concerning the development of pressure vessel design in Britain are, first, whether it is justifiable to increase the allowable design stress and, secondly, whether the basis for assessing the allowable stress at normal temperature should remain the ultimate tensile strength of the material or its yield strength. The current trend in Continental Europe is towards an acceptance of the yield stress (or proof stress) divided by a factor of 1·5 as the permissible working stress in a vessel shell. In Germany such a method of calculation has been used, with official approval, for some twenty years, and there has been no evidence of unsafety of operation of vessels so designed due to inadequate wall thickness. The use of the yield or proof stress as a basis for design stress is attractive because it is a step towards making the design process more rational. It is also attractive because (assuming that a safety factor of 2/3 is used) the weight and cost of a vessel for any given duty is reduced.

However, so far as Great Britain is concerned, it is very doubtful whether the introduction of a revised basis for acceptable design would result in greater standardisation of manufacture. In fact it is more likely that such a revision would form part of a special additional code and would add to the existing diversity. Taking the broad view, the interests of overall economy would, at the present stage, best be served by the unification of British codes and by broadening the scope of the pressure vessel section to cover the high-alloy and non-ferrous materials currently used in the chemical and petroleum industry. In Britain the practice of manufacture and use of boilers and pressure vessels is soundly based, and the codes have many desirable features; the classification of vessels, for example, and the system of approval of manufacturers which is incorporated in Lloyd's Rules. Future code development is only likely to be effective if it starts from this firm foundation and codifies and develops British practice on the basis of common agreement, acceptable to manufacturers, users, and classification societies alike.

Summary and Conclusions

1. There are wide differences in the degree of local authority given to codes and in the scope of the codes examined. Experience suggests, however, that this difference is not reflected in different levels of safety achieved by vessels constructed in the different countries ; on the contrary, the safety standard is almost uniformly high.

2. There is broad agreement as to the essentials required for sound design, except that in one group of countries the permissible design stress is equal to one-quarter (or some smaller fraction) of the ultimate tensile stress, whilst in the other group the permissible stress is two-thirds (or a smaller fraction) of the yield point or proof stress of the material. There is no evidence in general experience of any greater incidence of failure with either one or the other of these design criteria.

3. Great Britain and France are exceptional among the countries examined in that although national codes exist, no single code is either officially recognised or universally accepted, nor is any code-administering body so recognised or accepted.

4. It is considered that the establishment of a single boiler and pressure vessel code with a single administrative body would be a most desirable step towards standardisation and economy in the industry which manufactures and uses boilers and pressure vessels in Britain, and that any development towards increased permissible stresses should be secondary to the unification and strengthening of existing codes.

PRESSURE VESSEL DESIGN REQUIREMENTS IN THE NEAR FUTURE

The conventional method of calculating the scantlings of a pressure vessel may be described as a single-design-stress approach to the problem. The "design stress" is derived by dividing arbitrary and somewhat large factors of safety into several conventional mechanical strength properties (ultimate tensile strength, yield and creep rupture stress) of the material at temperature and selecting the lowest dividend as the design stress. This stress is inserted into conventional formulae for calculating the minimum thicknesses of cylindrical, spherical, toroidal, and conical parts of the pressure vessel.

The factors of safety currently in use are of the order of 4½–3 on the ultimate tensile strength, and 2–1½ on yield or creep rupture stress. Clearly, no move to improve pressure vessel design methods can culminate in truly economic designs so long as minimum permissible thicknesses are tied to such arbitrary design stresses.

Let a new approach therefore be made by defining an idealised pressure containment project as being one in which ;

(1) the vessel is comprised of one thin pure geometric shape, such as a sphere or an infinitely long cylinder, having only pure membrane stressing with no deliberate or accidental stress intensifications ; and

(2) the conditions of operation comprise only steady internal pressure at constant temperature, with no corrosive media present and no limitations on elastic inflation with pressure.

Then, under these ideal conditions, there would be no reason why the membrane stress should not be 99 per cent of a suitable minimum probability value of the yield or creep rupture stress of the material at the working temperature. This then could be the basic design stress given in the codes. The design stress should not be derived on the assumption that there will always be stress intensifications of the order of 2 or 2½ due to the presence of unreinforced holes or improperly designed discontinuities. This merely encourages the automatic acceptance of the inevitability of inferior design. On the contrary, there should be a bonus for good detailed design and accurately executed construction. It should take the form of permitting a high design stress in areas where there are no stress intensifications, and lowering it only where there are significant departures from ideal design or operating conditions.

Such departures may take one of two general forms ;

(1) the presence of unavoidable areas of stress intensification due to either design or manufacturing departures from pure shapes ; or

(2) the possibility of there developing in the pressure vessel modes of failure other than simple yield or creep.

These two types of departure from ideal conditions will be considered separately.

Dealing first with stress intensification, in the last twenty years a large effort has gone into both experimental and mathematical determinations of the detailed stress distributions in various shapes of pressure part. This effort on stress analysis is potentially one of the keys to the creation of better designs. For instance, if it can be shown that a common form of manufacturing imperfection (such as 1 per cent out-of-circularity) causes a stress intensification of, say, 1·5, and if a deliberate form of stress intensification in the same shell is not additive (for example, a large nozzle), then clearly there would be economic incentive towards designing the nozzle to an intensification factor of about 1·5, provided that this permitted a high membrane stress to be used. On the other hand, if the maximum permissible membrane stress is so low that, in effect, it allows stress intensifications of, say, 2·5, then not only is the shell thicker, but there is no incentive to eliminate stress concentrations up to this value.

Good though the stress analysis effort has been, it represents less than half the story for true design purposes. It is relatively simple to determine the stress system in a pressure part, but to date there has emerged no generalised method of interpreting an intensified stress system in terms of the design thickness to be used for the conditions of operation. Broadly speaking, it is known that a stress intensification which involves a large conjoint cross section of highly stressed metal must be taken at its numerical value, whereas an equal intensification which is highly concentrated and supported by lower stressed material is of less concern. However, no numerical formula of general applicability to practical cases has yet been promulgated. This is partly because of the variety of modes of failure which may develop in a pressure vessel.

Before the effect of an elastic stress intensification on the performance of a pressure vessel can be assessed, it is necessary to postulate the mode of failure which is to be considered. This may be one, or a combination, of several as follows :

(1) Excessive elastic deformation leading to unacceptable change of shape, to maldistribution of support loads, to leakage at mechanical joint, or to elastic instability or buckling.

(2) Excessive short-term plastic deformation leading to similar troubles as above, including plastic instability or buckling.

(3) Excessive long-term creep leading to low-elongation creep cracking, to unacceptable change of shape or to plastic instability or buckling.

(4) High strain fatigue leading to cracking, and eventual leakage or rupture.

(5) Corrosion fatigue, leading to the same.

(6) Stress corrosion, leading to the same.

(7) Fracture initiation and propagation under low applied stress.

Much research work is needed to translate representative types and magnitudes of elastic stress intensifications into their corresponding effectiveness factors when designing against each one of the above-mentioned modes of failure to perform the required duty. At first glance the task might seem impossibly complex, but simplification results from the proper selection of materials. Also design against some contingencies may guard against certain others, and few specific vessels would be potentially subject to all the contingencies mentioned. Other papers in this symposium show that much information of the kind needed is already being accumulated.

It is perhaps pertinent to point out that a vessel has to withstand not only the conditions imposed during operation, but also those prevailing during manufacture, transport, erection, pressure-testing and start-up. All these conditions should be reasonably known to the designer. Moreover the initial pressure test should be removed from the realm of arbitrary regulation, and should become a test deliberately designed to demonstrate certain prestated features of the vessel's ability to perform the duty which will be imposed.

From the foregoing thesis the conclusions may be summarised as follows :

(1) Raise the basic coded design stress to the highest value permissible for pure membrane stressing and idealised steady pressure and temperature.

(2) Factor separately each significant departure from pure membrane stressing and idealised steady pressure and temperature.

(3) Set in motion the necessary additional research work to determine the real effects of departures from pure membrane stressing and idealised steady pressure and temperature in relation to the modes of failure against which pressure vessels have to be designed.

(4) Act promptly in revising both mandatory and recommended codes upon the results of authenticated research and experience.

(5) Revise the basis of the initial pressure test so that it shall be deliberately designed to demonstrate prestated features of the vessel's ability.

It is submitted that the principle behind conclusions (1) and (2) could be adopted now, even though the departure factors had to be established on presently available experience and data. With the accumulation of research and experience and the advent of superior designs, the departure factors would be expected to diminish.

Shipbuilding Returns

THE returns published by Lloyd's Register of Shipping for the quarter ended December 31, 1960, show that in Great Britain and Northern Ireland 258 steamships and motorships of 1,984,000 tons gross were under construction: this is the lowest figure since June, 1946, the highest figure being 2,345,408 tons at the end of 1957. During the quarter fifty-three ships of 257,223 tons was commenced, sixty-seven ships of 376,222 tons were launched and fifty-seven ships of 322, 653 tons were completed. The total launched during the year amounted to 1,324,000 tons gross, the corresponding figures for Japan and Germany being 1,725,000 tons and 1,101,000 tons respectively. Oil tankers, totalling forty-six ships of 806,527 tons, represented 47·6 per cent of the total tonnage under construction. Tonnage for registration abroad amounted to thirty-six ships of 312,823 tons or 18·5 per cent of the tonnage building. Tonnage under construction abroad amounted to 1140 ships of 6,972,894 tons gross and the commenced, launched and completed figures are respectively : 399 ships of 1,733,787 tons, 437 ships of 1,753,626 tons, and 481 ships of 1,863,280 tons, all of which show an advance over the previous quarter.

Oil tankers building totalled 183 ships of 3,118,947 tons, and represented 44·7 per cent of the total tonnage being built. Tonnage for export amounted to 3,122,351 tons or 44·8 per cent of the total under construction. Throughout the world there are under construction 1398 ships of 8,667,082 tons gross of which 19·5 per cent are being built in Great Britain and Northern Ireland. Oil tankers under construction totalled 229 ships of 3,925,474 tons or 45·3 per cent of the ships building in the world. Ships to be classed with Lloyd's Register accounted for 4,457,465 tons or 51·4 per cent of the total.

LETTERS AND LITERATURE

Letters to the Editor

FLOODS

SIR,—I should like to correct a mistake in my article on "Floods" in your issue of January 20. On page 83 in "section (*b*) *The Nile*" the following sentence occurs: "The cubit was therefore a variable quantity which might decrease to lower the height of a flood."

In the above sentence delete "therefore" and read "increase" for "decrease."

Egyptian taxes used to be fixed annually according to the reading on the Nile Gauge on Rodah Island near Cairo on a day in August, when it was (and is) possible to say whether the flood was going to be good or bad.

Research has shown that the length of the cubit has varied during the ages from 480mm to 1481mm. The favourite figure is about 540mm, but several values appear to have been in use at the same time. To avoid any change in taxation, harmful to the Treasury, a high value could be chosen for a high flood, thus reducing the height in cubits and vice versa in a low flood.

The late Kamel Ghaleb in a paper dated 1943, gives six values for the cubit in use before the foundation of Baghdad and a further term dating after that foundation. Newton tried to determine what "cubit" meant but gave it up.

F. NEWHOUSE

Twickenham,
January 22, 1961.

MILLIONS TO BE SAVED, WITH IMPROVED SAFETY

SIR,—In view of Mr. C. F. Cobon's somewhat extravagant language on the subject of road and rail casualties it will be my aim to follow your lead and—borrowing from your article on road safety, August 5, 1960—supply comparisons, in order "to put the matter into a perspective less charged with emotion than usual."

Weekly in this country there are about 16,000 births and 11,000 deaths; of the latter some 500 are violent. The largest element in the annual 26,000 deaths by violence comprises home accidents. In 1958 they accounted for 8109; highway deaths came next with 5970. Suicides run steadily at around 5000 p.a.; work, play and homicide account for most of the rest—I shall come to railways presently.

Since accidents will always be with us, and no absolute standard of safety can be set, international comparisons on a *per capita* basis will always be relevant. The highway fatalities in 1958, per 10,000 head of population, in a dozen comparable countries, were as follows: Austria, 2·57; Western Germany, 2·20; Switzerland, 2·17; Australia, 2·16; U.S.A., 2·15; France, 1·83; New Zealand, 1·66; Italy, 1·47; Denmark, 1·37; Sweden, 1·26; Great Britain, 1·19; Northern Ireland, 1·00.

In case these statistics tend to reduce the matter of road risks in Britain to such proportions that it ceases to interest, I mention that my figures are all obtainable from the Royal Society for the Prevention of Accidents, which body is in the forefront of the present successful campaign to stigmatise British road behaviour and shock the Government into further repressive measures against the motorist; Mr. Cobon does not stand alone. Moreover the railways' parallel record, which he eulogises, involves consideration of an interesting new factor, for the *per capita* basis must be modified when applied to railway casualties; the entire population do not venture on to railway property every day, as they do venture on to the highway system, and it is, therefore, a matter of determining first what proportion of the population expose themselves to the risk of becoming a rail casualty on the average day.

For brevity British Railways alone will be considered, without London Transport or other lines. In 1959 their passenger journeys numbered 1069 million, which is a little fewer than 3,000,000 a day. The vast majority of them will have been one leg of a day-return journey, and the single journey will have been offset by the four or more journeys often made by one individual in the course of a day; accordingly some 1,500,000 persons used B.R. as passengers on the average day in 1959. In addition there were the 519,000 railway employees, five-sevenths of whom will have been present on the average day. Altogether, allowing for a modicum of trespassing, B.R. can be said to have had an average of 2,000,000 potential victims daily, compared with the highways' 50,000,000—one-twenty-fifth.

Rail casualties are very fully recorded in the Annual Report on Railway Accidents, though some of them require more digging out than perhaps Mr. Cobon had time to undertake. For the year 1959 B.R.'s fatalities were: passengers 24, railway servants 156, others 33, suicides 149, trespassers 101: total 463. It might be argued that the suicides should remain in the calculation, for railways provide every facility for the act whereas roads do not; however let them be struck out, reducing B.R.'s 1959 fatalities from 463 to 314. Thus from among the 2,000,000 persons venturing within their reach B.R. snatched 314. If the highways had been of equal lethality, from among their 50,000,000 they would have taken 7850. Fortunately, being more lenient, they took only 6520.

But the broad subject of this correspondence is the conversion of Britain's railways into roads from which pedestrians, bicycles, mopeds and scooters would be excluded; the 1959 highway fatalities in these categories (included in the 6520) aggregated 3556; accordingly the relevant comparison is not between 7850 and 6520 for rail and public highway as given above, but between 7850 and 2964 as the fatality indices for unconverted railways and converted railways respectively. In addition the converted railway system would attract traffic away from the highways, leaving them safer, and there are many other subsidiary factors reinforcing the argument for railway conversion as a safety measure, though I lack the space to set them out here. A longer letter might constitute that exaggeration of the importance of accidents which you deprecated on August 5, 1960.

The other matter raised by Mr. Cobon seems to have been disposed of already by yourself, Sir, on November 4, 1960, when you wrote: "No one who has travelled along the length of M1 by car or coach at high speed will ever doubt again the ability of a road vehicle to provide as much comfort, steadiness and quietness at speed as an express train."

Finally, I am authorised to report that on the M6 Preston by-pass, which has been in service longer than M1, and comprises carriageways 24ft wide whereas M1's are 36ft, the latest score is: Vehicle-miles, 35,000,000; Fatalities, nil.

T. I. LLOYD, Brigadier

Guildford,
January 19, 1961.

Book Reviews

The Testing of Electrical Machines. By LAURENCE H. A. CARR, M.Sc.Tech., M.I.E.E. Macdonald and Co. (Publishers), Ltd., 16, Maddox Street, London, W.1. Price 50s.

As the author points out early in this book, the basis for British practice in the testing of dynamo-electric machines underwent a radical change about the middle of the century, culminating in the publication of British Standard 2613 : 1957 "The Electrical Performance of Rotating Electrical Machinery." Previously British practice, generally, was to specify that all electrical machines were to be capable of carrying 25 per cent. overload for a period (usually two hours) following a continuous full-load run, without incurring a specified temperature rise that would harm the insulation. In B.S. 2613 : 1957 the basis for the rating of motors was brought into line with that for large generators in that continuous maximum rating (c.m.r.), without any provision for sustained overload, became standard practice in this country.

From this start point the author proceeds to delve thoroughly into the subject. His treatment of it is conditioned by his appreciation of the fact that testing has two main objects: first to determine whether the machine concerned is capable of performing the duty intended; and, secondly, to give experimental confirmation of design forecasts and yield information for future designs. This being the author's approach, the reader will expect something more than a superficial recital of test procedures and he will not be disappointed. The book contains numerous examples of actual tests, recorded in considerable detail, with appropriate explanations and comments upon points such as divergences of observed values from those anticipated.

Some idea of the scope of the text can be gleaned from a list of the contents. The book begins with general considerations regarding testing and then covers the following subjects : d.c. machines ; induction motors ; operational theory of synchronous machines ; synchronous machine tests ; synchronous motors ; sudden short-circuit of an a.c. generator ; further synchronous theory ; the a.c. generator ; the synchronous condenser ; the turbo-generator ; and balancing. There are also chapters on the testing of work in progress ; precautions to be taken during erection for test ; and on test equipment and its use. An appendix describes the two-axis method for the predetermination of the excitation needed by a synchronous machine.

To keep the text within reasonable bounds, single-phase machines and three-phase commutator machines are excluded and only normally applied tests are described. Inevitably, therefore, some interesting test procedures are omitted, such as the ingenious system, described by Friedlander, for the simulated load testing of large turbo-generators with the help of reactor banks. Nor is it a serious criticism to observe that the test methods dealt with in the book appear to be based on the practice of a single manufacturer ; for the author makes a special point of explaining the tests instead of merely describing the procedure. We can, therefore, endorse the author's claim that this book should be of use not only to test staff, but also to junior designers, inspecting engineers and lecturers on electrical machinery.

Unusual Locomotives. By ERNEST F. CARTER. Frederick Muller, Ltd., Ludgate House, 110, Fleet Street, London, E.C.4. Price 21s.

THE author of this book has attempted in a relatively small volume to tell the story of the development of the locomotive from the earliest days, extending back to Trevithick's locomotive of 1803 up to the present time, making special reference to the many examples of what are called unique and unusual locomotives introduced at various times. To anyone reasonably conversant with the history of the development of the steam locomotive, it will be evident that to do justice to the subject must have involved considerable research. Only a casual glance over the pages of this book is sufficient to show that the author has succeeded in no small measure in finding locomotives of unusual design and construction.

Taken as a whole, the illustrations, which are either drawings or photographic reproductions, may be said to be adequate for their purpose. They certainly reflect the considerable time which must have been taken in collecting the information required. Such being the case, it is unfortunate that the text has not been more carefully compiled. On going over the pages, we have been disappointed to find quite a number of unexpected errors.

Referring to British locomotive developments, we find mention made of the famous broad gauge Great Western locomotives built by Sir Daniel Gooch. One of these "Great Western's," we are informed, attained a maximum speed of 78 m.p.h. on many occasions. This we are inclined to think is an exaggeration. According to Charles Rous-Marten, a former valued contributor to our columns who was an acknowledged authority on locomotive performance, writing in *The Engineering Magazine* of April, 1898, "Some Notable Speed-Trials of British Locomotives," these remarkable locomotives of the 8ft "single" driver classes, namely, the "Iron Duke," "Great Britain" and "Courier," when specially tested in 1848 on a falling grade of 1 in 100, attained a maximum speed of 78·2 m.p.h., and that much later when he made several trips with them "only on two occasions did they equal the speed of 1848, although having the advantage of higher steam pressure."

Similarly, later, when referring to the so-called Railway Races of 1895, it is stated that the London and North Western engine "Hardwicke" often ran from Crewe to Carlisle at a mean speed of 67 m.p.h., which is quite incorrect. This engine certainly did on one occasion make the run at this speed on the final night of this historic competition. While on this subject of North Western locomotives, mention may be made of F. W. Webb's three-cylinder compound express locomotives. The author mentions the first of these, No. 66, "Experiment," and goes on to say, "Two identical engines were later built; one a 'simple' and the other a 'compound,' and it was found that, whatever a 'compound' could do, a 'simple' could do more efficiently." To what this remark refers we are at a loss to understand. Later, another effort is made to refer to these locomotives, when we are informed that Webb built the "Experiment," "Precedent," "Dreadnought" and the "Teutonic" classes, each being improvements in which various methods of compounding were tried. We suggest that the "Precedent" class were not compounds and that the others named were all compounded on Webb's three-cylinder system, except that one of the "Teutonics" when first built had different sized cylinders for some purpose, but was later altered to conform to the others of this class.

The remarks made concerning the Liverpool and Manchester locomotive No. 32, "Experiment," appear to require amendment. In describing this as having "its cylinders placed vertically over the leading wheels," we think the author is confusing this engine with the "Hibernia," also built by Sharp, Roberts & Co. The engine "Lablache," built by E. B. Wilson, is stated to have been driven by an oscillating shaft drive. This is not correct : as illustrated, such a drive would not have been possible. Actually, it had a pair of cylinders between the frames driving a crankshaft having outside cranks driving the coupling rods. We have mentioned only some of the errors noted when going over the pages of this book. They are, however, sufficient to raise doubt as to the authenticity of a book that might otherwise have been of very real value. The presentation by the publishers is pleasing and the subject interesting. If, therefore, a further edition is ever contemplated, it would seem worth while taking some trouble to correct mistakes.

Engineering Data Processing System Design. By ARTHUR D. EVEN. D. Van Nostrand Company, Ltd., 358, Kensington High Street, London, W.14. Price 49s.

THIS is primarily a practical book, written with the intention of helping the reader who proposes to introduce a system of data processing in an engineering organisation. The author carries out this design with clarity and attention to detail. The form of data processing described is concerned with the management of engineering drawings, parts lists and allied documents, using microfilm records mounted in punched cards. In considering the design of the system, the author begins with the choice of personnel for the planning group, and discusses the psychological aspects of the impact of mechanisation on those who have been responsible for the previous manual systems. At a later stage a chapter is devoted to securing management approval. The book then proceeds to the details of installing, operating and controlling the system, discusses its later expansion, and concludes with a review of future possibilities in this field. All these sections are illustrated with examples of American equipment. A glossary of terms sometimes provides unexpectedly pleasant reading, such as the information that a reproduction room is "an assembly of reproduction equipment into an area which is devoted solely to the making of reproductions."

Messen an Zahnrädern und Getrieben. V.D.I.-Berichte Vol. 32 (1959). Collected papers of the V.D.I. Meeting in Frankfurt-on-Main, 1957. Düsseldorf : Verein Deutscher Ingenieure, (22a) Düsseldorf 10, Prinz-Georg-Strasse 77-79. Price DM.38.60. (V.D.I. members and subscribers receive a 10 per cent rebate.)

THE present issue of *V.D.I.-Berichte* contains the full version of ten lectures and the associated discussion from the meeting held by the V.D.I. in Frankfurt-on-Main in November, 1957. The subjects of the papers were "Noise and vibration measurements of gear trains and their evaluation" (H. Zink) ; "Experiences with static and dynamic strain measurements on gear teeth" (G. Niemann and H. Rettig) ; "Causes of machining errors in gear milling and shaping, and their determination by means of novel electronic gear measuring equipment" (W. Höfler) ; "Measurement of uneven rotation of gear cutting machines" (R. Piekenbrink) ; "Acceptance tests for gear hobs, especially those of the highest precision" (W. Dreyhaupt) ; "Problem of measurements in the case of large gears" (A. Budnick) ; "Measurement of flank finish" (W. Hagen) ; "Measurement and testing of very small gearwheels" (L. Meyding) ; "The theoretical basis for tests of bevel gears" (G. Zieher) ; and "Measurement and testing in the manufacture of interchangeable bevel gears" (G. Apitz).

Books Received

Merchant Ships ; World Built. Vol. VIII. Adlard Coles Ltd., 7, Brunswick Place, Southampton. Price 45s.

Self Organizing Systems. By M. C. Yates and Scott Cameron. Pergamon Press, Ltd., Headington Hill Hall, Oxford. Price 60s.

The Craftsman Engineer. By Raymond Lister. G. Bell and Sons, Ltd., Publishers, York House, Portugal Street, London, W.C.2. Price 15s.

Innovations in Building Materials : an Economic Study. By Marian Bowley. Chatto and Windus, Ltd., 40-42, William IV Street, London, W.C.2. Price 70s.

Mathematical Tool Kit for Engineers. Second Edition. By H. A. Webb and D. E. Ashwell. Longmans, Green and Co. Ltd., 6 and 7, Clifford Street. London, W.1. Price 15s.

Basic Synchros and Servomechanisms. Part 2. Developed by Van Valkenburgh, Nooger and Neville, Inc., The Technical Press Ltd., 112, Westbourne Grove, London, W.2. Price 16s.

Machine Drawing and Design. By W. Abbott. Blackie and Son, Ltd., 17, Stanhope Street, Glasgow, C.4. Price 21s.

Modern Workshop Technology. Part II. Second edition. Edited by H. Wright Baker. Cleaver — Hume Press, Ltd., 31, Wright's Lane, Kensington, London, W.8. Price 55s.

Applied Chemistry for Engineers. Third edition. By E. S. Gyngell. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 28s.

Molecular Distillation. By G. Burrows. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 35s.

Management and the Social Structure of the Firm

By Professor LADY WILLIAMS

The last two decades have seen profound changes in our understanding of the problems inherent in large-scale enterprise. Collective agreements between trade unions and employer's associations, covering a whole industry or occupation, provide the framework of working conditions within which each firm must carry on its operations, but they do not offer any answer to the thousands of detailed questions that emerge in the variations of day-to-day working of individual enterprises : hence the constant interruptions to work as a result of shop steward action. Older attitudes to this situation were altogether too mechanistic. They assumed that economic productivity and good morale were a function of (a) *the right economic incentives in wages, bonus schemes, &c.;* (b) *healthy working conditions and welfare amenities; and* (c) *some formal machinery for consultation. Ideas are slowly beginning to change as we realise that a business enterprise is also a complex social organisation, with its own heirarchy of responsibility and status, its own power structure and its interlocking network of groups of all kinds, each with its own conventions and its own pattern of loyalties. The assumption that "industrial relations" concern only the relations between "management" and "men" seen as two homogeneous bodies ignores the realities of the social structure of a firm. A book recently published by Mr. Wilfred Brown, general manager of the Glacier Metal Company* (Exploration in Management, *Heinemann*, 30*s*.) *discusses some of the issues involved in this conception of the firm as a social organisation.*

IT is now more than a quarter of a century since Elton Mayo published the results of the famous Hawthorne experiment which he had carried out over a period of years in the Chicago works of the Western Electric Company during the late 'twenties, and in so doing gave a new direction to thought about industrial relations. Already by the beginning of the century there were many employers willing to recognise that a worker is not a machine and that his economic productivity, as well as his health and happiness, can be profoundly affected by the circumstances of his work. It is surprising to us now that it took so long for this to be accepted; but we can see how recent has been this change of view if we remind ourselves that, during the first world war, most factory legislation was suspended in the mistaken belief that by lengthening hours of work, cutting out rest days and dropping "welfare" protective requirements, output could be proportionately speeded up. It took a good many years of special investigation into the causes of lowered production to prove conclusively how completely fallacious this idea was. A sudden spurt is possible to most healthy people provided there is no attempt to keep the spurt up too long: but the marathon walker cannot move at the rate of the sprinter. If the work drive is kept up it soon results in a general slowing of the pace, damage to machines and to materials and a higher accident and absentee rate. Shorter hours of work, well-lighted, well-ventilated rooms, rest pauses, canteens, days off, and so on, were shown to be essential to efficient economic production and not the gifts of a benevolent, paternal employer. Thus, good environmental conditions came to be normal practice and not the exception.

With this greater expenditure of thought and money on the welfare of the worker it came as a great disappointment to find that the difficulties of industrial relations remained as serious as ever. The Western Electric Company, for example, was accepted as having provided excellent working conditions in its Hawthorne works, yet there was no doubt that productivity was consistently below what could be reasonably expected without involving strain, and morale was poor. What was the cause? Was there insufficient incentive? Would piece work make a difference? Were the hours of work too long? Too short? Wrongly scheduled? Were environmental conditions in need of change—lighting, temperature, seating, &c.? Elton Mayo, Professor of Industrial Research at the School of Business, Harvard University, was asked for advice and decided to carry out a series of controlled experiments. A small group of girls were invited to co-operate with him by allowing the conditions of their work to be constantly changed, whilst those of a control group, engaged on the same processes, remained unaltered. The results are now well known—no matter what changes were made, output went up! Hours were shortened and lengthened, rest pauses introduced and removed, lighting improved and put back to its original state, piece rates established and replaced by time rates. Nothing made any difference, the co-operating group worked and worked and output went up and up. It was evident then that some other factor was operating and Mayo came to the conclusion that the earlier approach had been too mechanistic. It was treating the worker like a slot machine—you put the penny in the slot—shorter hours, better lighting or what have you—and expect the drawer to deliver the goods. No penny, no goods in the drawer. But human beings are not machines and do not respond in that way. It seemed to him that the astounding results were due primarily to the fact that this small number of workers became a closely integrated group who felt themselves stimulated and excited by the realisation that they were individually and collectively "involved" in what was happening.

Further experiments with other sections of the labour force confirmed his belief in this hypothesis. A business is not simply a collection of individuals brought together by the chance of earning a living in that type of employment; it is itself a complex social structure which, in common with every living community, develops its own system of hierarchy, its overt rules and understood customs, its interlocking and overlapping loyalties, its antagonisms and conflicts. Every schoolboy knows this from his own experience but because it is so rarely put into words it does not become part of his intellectual knowledge to be applied to other spheres. The headmaster enforces certain rules; but it is the social pressures exerted by the boys themselves that govern day-to-day conduct—what is done and what is not done, what is worn and when, who speaks to whom and how. Very often conflict arises between different claims of correct behaviour: for example, how does one decide what to do when one recognises that one should not lie to a master but also must not sneak on a schoolfellow; or one must be loyal to the school, but one has a special loyalty to one's own group. Who makes these rules? What foundation of reason do they possess? By what subtle process do they change as time goes on? How are the family codes of behaviour which are enforced at home by parents reconciled with those of the school? If we could answer these questions with any degree of certainty we should be much farther advanced than we now are in our understanding of national, international and industrial problems; for the same factors influence us in the whole of our life. Each of us is a member of innumerable social groups, big and little, close and remote, intense and diffuse—from our own immediate family to our country, U.N., and the world—each conditioning us to certain attitudes of mind, certain patterns of behaviour; and each, often, coming into conflict with one another.

Joint Works Councils and Similar Bodies

Sociological discussion has gradually begun to familiarise us with these ideas in a general way, but we owe it to Elton Mayo to have insisted that a business is no exception to the nature of human associations. Many of the practices which seem irrational and anti-social or even to operate against the interest of the men themselves when looked at *in vacuo*, can be more easily understood when seen in this context. For example, the common practice of restricting output, despite incentives in the form of piece rates and bonuses, may have had its origin in the fear that basic rates might be cut if some workers produced too much but, though the development of powerful trade unions has made this fear illusory, well-established codes have grown up which exert an immense influence and which few workers would dream of flouting. It is as anachronistic as the polite man's readiness to walk on the outside of the sidewalk when with a woman, though the roads are no longer running sewers; but it persists as part of accepted convention.

Or consider the bitter resentment felt, and expressed, when technological changes de-skill a job. Even though the new process may allow higher earnings, the loss of status involved is bitter to men whose skill has before put them in the upper reaches of the workers' hierarchy. Their conscious allegiance may be given to an egalitarian and classless society; but their reactions to the situation are conditioned by attitudes and loyalties of quite a different social structure.

The recognition of these "imponderables" is gradually beginning to modify managerial ideology, but because they *are* "imponderables" and because they deal with concepts which, while matters of general experience, are usually below the level of conscious awareness, it is extremely difficult to give them practical effect. Accustomed as we are to formal democratic procedure in political life, it seemed that the introduction of similar representative bodies into industry would give each section an opportunity to express for itself the matters on which it felt most deeply. As long ago as 1917 the Whitley Committee

recommended that firms should establish Joint Works Councils so that groups with some common identity of interest within the business could elect spokesmen to discuss with management those issues which were of special concern to the firm, within the framework set by the general conditions negotiated by the unions and employers' associations; but very little came of this. There were, however, a number of firms whose managing bodies were keenly alive to the need to develop a constructive " human " relationship within their works and there was a good deal of experiment in various types of Works Councils—sometimes jointly representing workers and management, sometimes consisting solely of workers' representatives with ready access to management when they had agreed on some issue. In this way it was hoped that interest in the firm as a whole, and a sense of corporate responsibility for the business, might replace the pleasure and pride in the performance of a skilled task that were now denied to so many through the increasing mechanisation of work.

By and large, it must be admitted that this experience has not been a very happy one. Though some Works Committees have done valuable work in a narrow sphere, they have certainly not demonstrated any great degree of constructive value. Detailed and painstaking inquiries into the operations of many such bodies in a variety of industries, made during recent years, give an almost uniformly depressing account of their lack of vitality. They start with enthusiasm and vigour—probably with excessively high expectations—but rapidly lose any semblance of life and growth. The workers complain that only trivial matters are discussed and that, therefore, it is not worth the bother and time taken in attending meetings to vote for their representatives; the men elected to the councils complain that nobody backs them up and that the men they represent are too ready to label them boss's men if they don't succeed in getting everything they have asked for, and the management gets discouraged and is willing to believe that the men have really no idea of what is involved in running a business and that the more you give them, the more they want.

Influence of Trade Unions

Yet that some form of provision for discussion within a firm is essential is not open to question. It has been forced on our attention recently by the spate of strikes called by shop stewards within an individual firm on the plea that there is nobody else to protect those for whom they speak. But even without this pointer it does not require much knowledge of the structure of modern industry to be convinced of its importance. The man on the shop floor feels that the modern giant trade union is too remote from him to be concerned with the details of his day-to-day working life; yet this is what looms largest in his mind. It is, after all, as if the local resident of Slocombe-on-Mud had to wait for Parliamentary legislation before a decision could be taken about paving the village market place. Moreover, British trade unionism has traditionally developed on an occupational rather than an industrial or works basis. This means that in any fairly large firm there may be members of a dozen or more unions; each union guards the interests of its own members but there is nobody who can speak for the workers as a whole. Yet this is exactly what is so often needed. The increase in scale of the typical firm demands the co-ordination of an enormous number of separate interests to form a harmonious and viable whole. The men and women who carry on the basic productive processes, the engineers who set and maintain the machines, the transport workers and packers, the clerks, the sales staff, the designers, the buyers of raw materials, the advertisers, the travellers, the forecasters, the supervisors, &c.; each is concentrating on some job of which he has special knowledge and is naturally inclined to think it of the utmost importance, more important than most of the others. Finally, in some way all these specialist tasks and skills must be brought together in such proportions that there emerge the kinds of products the public wants and at prices that the market is prepared to pay, and to buy in sufficient quantities to keep the firm fully employed.

Facts and Humanity

To add to the difficulty, the rate of change in markets, sources of supply and technological processes is bewilderingly rapid, and failure to adapt the work to these changes soon proves fatal. These problems are primarily economic; they involve decisions about costs and prices, the relative advantages of using this or that material, this or that method in producing the goods that can compete favourably with the rivals in the field. Yet whilst the ultimate criterion is, and must be, economic viability, it is not, and cannot be, the only one. Each decision taken alters the work of one group or another and thus changes their relative positions in the firm. The fact that the business is a living community makes it imperative to take into account the accepted codes of behaviour, the recognised hierarchy of status, the understood expectations for the future, the attitudes of mind, the judgment of what is right or wrong in treatment and what infringes customary privileges. All of these are as much " facts " in the situation as the prices of the raw materials and the trends in consumer tastes, and have to be given their due weight in coming to a decision.

It is difficult enough to reach a sound conclusion when only economic facts are part of the calculation—rate of output for so much change of input of varying factors—but how infinitely more difficult when the matters to be weighed against one another are so different in kind. Yet, unless some way of reconciling them is found that commends itself to the sense of justice of the majority of those concerned, the business is very unlikely to be successful.

Industrial Relations

It is probably due to the historical developments in the field of organised labour and the consequent growth of negotiating machinery between unions and employers that the term " industrial relations " has come to have an unduly narrow connotation. Until the large joint stock company became the typical business unit, management and ownership were not divorced from each other and the number of men engaged in " brain-work " was comparatively small in contrast with the numbers of manual workers. The pay and conditions of this small group were entirely a matter of individual bargaining and individual variation, and formed a marked contrast to the collective agreements made by unions on behalf of their members which had resulted in the establishment of occupational rates of pay. In general, this situation has remained in being despite the development of the modern large scale firm as the modal contemporary enterprise; and in consequence the words " industrial relations " at once brings to the minds of most people a picture of " workers " on the one hand and " management " on the other, as if they were two clearly defined groups, each with a common identity, but between whom some bridges of common purpose might be built. How entirely false is such a picture requires only a moment's thought by anybody with knowledge of the inner structure of a firm. There is no marked gulf anywhere from the man on the shop floor up to the managing director; and to make a clear dividing line between management and workers involves a purely arbitrary decision. Where, for example, would one put the foreman? But even without this difficulty of separating sheep and goats, to assume that the men engaged in the non-manual tasks of a firm are all more or less of a piece is analogous to the assumption that there is not much difference in the nature of the work done by a subaltern and that of the field-marshal. Not only are there higher and lower steps in the chain of command but there are many side lines and branches of specialist jobs. There are, therefore, just as many opportunities for conflict, antagonism, frustration, bitterness, grievance, misunderstanding and all the other human reactions which result in lowered morale and inefficiency, amongst the non-manual ranks as anywhere else. To confine the problem of establishing good human relations within the firm to the job of discovering a harmonious *modus vivendi* between " management " and " men " is to-day an altogether anachronistic approach. The modern business is so complex an organisation and embodies so many differing specialist skills and spheres of knowledge that there may be just as great a barrier to understanding between, say, sales managers and production engineers, or between the headquarters man forecasting future consumer trends and the manager of a branch factory, as have ever existed between " staff " and " workers." In some way these contending interests must be harmonised and made to agree if the whole concern is to run economically and competitively, be capable of adjusting itself to new circumstances and yet retain the loyalty and willing co-operation of all those involved. It is the job of the science of management to find out how best this may be accomplished and of the art of management to do it.

The Social Structure of a Business

There has recently been published a book* which makes a notable contribution to the solution of this problem. Mr. Wilfred Brown, general manager of the Glacier Metal Company for the last twenty years, here gives the fruit of his experience in the command of a business employing 36,000 people. It is safe to say that no more thoughtful nor thought-provoking book has appeared for a very long time. One of its great merits is that it does not pretend to provide all the answers: here is no " Enquire Within upon Everything " for the manager. It reads, indeed, rather like an Interim Report, giving an account of the problems that demanded settlement in his own firm and the way he set about trying to deal with them. Where he fears he has failed, he says so frankly; where he has not yet been able to decide what to do next, he is equally candid. Even more striking, there is nothing here of the airy-fairy generalisations about the great importance of human relations in the firm, of the kind which raise the cheer in the after-dinner speech but, instead, an acute and probing mind is directed towards a diagnosis of the fundamental issues involved.

The Glacier Metal Company has long been a pioneer in its acceptance of the thesis that

*_Exploration in Management_, Wilfred Brown, Heinemann, 30s.

a business enterprise has a social structure of its own which must be clearly understood if it is to function at optimum efficiency. The problems occasioned by the impact of technological change on its working groups have already been discussed in a book which has become one of the standard works in this subject, and during the research which was undertaken in its preparation, those in control became acutely aware of the difficulties under which they laboured because of the lack of any generally accepted vocabulary. Words which are used with great frequency, such as manager, supervisor, specialist, policy, authority, &c., have no precise connotation which is universally recognised. Thus there are endless misunderstandings and endless time is taken up in arguing about the meaning of the words instead of the problems to which they relate.

Limits of Authority

In this book Mr. Brown tries to set down in precise terms what exactly is done by managers of different grades and specialisms, how the business is organised, who takes decisions about what, who has authority over whom and so on. He explains exactly how and why the company uses terms as it does in its documents and how and why it puts down in a written document, which can be constantly read and consulted by all, the scope and limits of each job in its organisation. Only a few of the fascinating themes which emerge can be touched on here. Take, for example, the limits of authority. A firm, perhaps, prides itself upon its freedom from red tape; it has practically no rules and regulations because it wants to encourage its section managers to use their own initiative. So *X* takes certain steps which, unknown to him, have serious repercussions on other departments. His superior then criticises him for not realising that, in such circumstances, he should not have acted without authority from him. But *X* was told to use his own initiative and make his own decisions. How is he to know the limits within which he can safely do this? In the course of years, if he has any sense, he will naturally learn by experience; but in the meantime he has made blunders which may have been costly to the firm and more than likely he will have developed an excessive timidity so as not to "blot his copy book." The fault lies with the firm itself which has not thought clearly enough what are the components of the job to which they have assigned him or have not made this clear to him. In a business, as in ordinary life, there cannot, in fact, be complete freedom for any individual, and initiative and flexibility will not be encouraged unless a man knows quite clearly within what boundaries he should operate.

Policy Making

How far policy making is centralised depends, of course, on the nature of the product and the techniques employed. But in no firm is it possible for all decisions to be taken by the chief executives. What is essential is that the level at which decisions of different kinds are taken should be clear, not only to the general manager, but should be explicitly stated to those under his command. In many businesses a "custom" grows up as a result of a number of instructions given at different times to meet *ad hoc* problems. This does not provide any principle of general application to guide men in a new situation for which there has been no exact precedent, and mistakes costing the company thousands of pounds may be the consequence of a decision which should not have been taken at that level.

This is nothing new in the theory and practice of public administration. In a Government department, for example, the line of command is made clear to every official and it is, perhaps, because this differs so much from industrial and commercial practice that there is often ill-informed criticism of bureaucratic red tape. But administrative principles are the same whether the enterprise is a big firm or a public body, though the end product is different. Similar problems of co-ordination and communication have to be solved. Who takes the decisions? Within what boundaries? After consultations with whom? With what degree of freedom to act despite lack of unanimity? And so on. It is probably more difficult to formulate such principles within a large firm because the constant changes in materials, techniques and markets demand constant modification of the organisational structure and it is, no doubt, on this account that so often changes are made in practice without being made explicit in words—until a crisis occurs and a serious loss is incurred.

Limits on Executive Authority

But even when this system of executive relationships has been carefully worked out and clearly expressed there remain other limits on those in authority. Decisions are of two kinds. The first embodies the application of an agreed policy to the multifarious detailed arrangements which must be made to implement it. For example, a firm has established certain principles on which promotions shall be made or persons dismissed. The decisions taken by any section manager with regard to a particular individual within his command are an application of this agreed policy.

The second type of decision taking is one that introduces some change into running the business and is not simply an implementation of an accepted course of action; it is in this second type that other factors have to be considered. No managing director, however absolute his power may seem to be, can, in fact, do exactly as he likes. Not only is he obviously bound to take into consideration the tastes and wishes of his consumers, for if they stop buying he ceases to function, and the over-riding authority of his board of directors, who may refuse to sanction a big investment in plant or buildings, but he is also limited by the necessity to persuade his employees to carry out the policy he sets. Every company has a whole series of established customs and practices which can be changed only with the consent of those involved, whether this consent is given formally or not. It is not common for foremen, accountants, technicians, senior managers and the like to elect representatives to put their case in a formal manner, but it is quite usual for a deputation to contact the managing director on a specific issue. If there are strong feelings about a radical change that is proposed, people get together and see that their feelings are made known. Whether one believes in joint consultation as a theory of management or not, it is, as Mr. Brown insists, an industrial fact. "Trade union leaders, politicians, industrial philosophers and others discuss the subject in moral and political terms. One will claim that workers have a right to take part in such discussions; another will discuss the benefits arising from the introduction of joint consultation and so on. The statements I have made are an attempt to avoid this controversy by pointing to the facts. . . . When a manager wishes to introduce changes into a company he must ask himself, 'Is this change in accordance with established agreements, custom or practice and will it be tolerated by those who work in the company?' Most managers avoid the reality of this situation and talk of joint consultation as a means of getting *advice* from employees. In fact, they are doing nothing of the sort; they are asking for *authority* to carry out the desired policy and, unless they get it, they cannot carry on."

This being, in any case, the position, it is best to institutionalise it and give formal opportunity for every sectional interest to have its views expressed. The Glacier Metal Company has, for this purpose, established a representative system which includes every grade amongst employees, even the most senior officers. At the outset there were many amongst this latter group who thought this inappropriate, but as time has gone on and managers have become more accustomed to taking part in the election of representatives to speak for their group interests or to acting as such themselves, the responsibilities attaching to this system and its relationship to their executive roles have gradually become more distinct.

The Works Committee in its Proper Context

Such a system, recognising as it does the fact that any group, of whatever eminence or seniority, or however lowly, has its own special place in the social structure of the enterprise, puts the position of the Works Committee, as described earlier, into its proper context. Instead of a completely false dichotomy—management and men—it embodies the concept of the firm as a community in which there is a basic foundation of common interest but in which there also exist many different groups, each of which has its peculiar attitudes of mind, special loyalties and patterns of behaviour.

This is sound sense; and it is equally sound sense to insist that this representative system will not be fully effective unless each person clearly understands that the role he is called upon to play as a link in the executive chain of command is different from that he assumes as a representative of his group. A junior manager, for example, must feel himself free to voice criticism of the higher command when he is giving the views of those who have elected him to represent them, and he can do this only if everybody in executive authority over him is clear on the different relationships in which they stand to one another in these two roles.

This was long the problem of the trade unions, for employers could not rid themselves of the idea that a workman elected to speak on behalf of his fellow workers was simply an insubordinate agitator. Indeed, it was not until trade union officials became full-time paid employees of the union and were no longer part of the work force of the firm that the process of collective bargaining could become fully established. Such a development is not possible within the firm for it is as an employee of the company that the elected representative has a right to be heard at all. Thus it is at once more difficult and more necessary for the two separate roles that are played by the same person in different circumstances to be explicitly recognised.

It is here that a particular problem arises with regard to the men on the shop floor. The position of the foreman or supervisor is almost always one about which there is much confusion. Very little attempt has yet been made to analyse the work of the person whose relationship to the man on the shop floor is the closest and most direct. Yet this is where most disputes and grievances originate. Indeed, until recently there was little acceptance of the belief that this job requires any

special qualities, much less any special training. There are now in existence a few perfunctory courses of training which, as is usual when training precedes job analysis, are marred by too many blurred and inchoate ideas of what they are trying to do. But the majority of firms do not expect even this amount of preparation and assume that this work can be done by any reliable workman who has been in the firm long enough to know its layout.

Failure to Fit in the Supervisor

Though the Glacier Metal Company does not act on this principle, Mr. Brown has to admit failure to fit the supervisor adequately into the organisation. In the firm as a whole there has developed a close personal relationship between those in command at any level and those under their control. This holds true all along the line from top to bottom—or almost bottom; for when it comes to the last link there is a breakdown. Here alone there is hostility between controller and controlled. In all other grades warmth of feeling, personal knowledge and tolerance of shortcomings characterise the two-way relationship between manager and subordinate; but this not true of the operator-section manager (the company's term for a supervisor). Here the attitude of the men under control is one of antagonism with a readiness to take pleasure in the exposure of the manager's mistakes. Why is there this break at the bottom level?

The explanation may lie in the exceptional difficulty at this point of affecting a clear separation between the executive and the representative roles of the foreman-operative relationship. It is the job of the supervisor to ensure that the machines are kept running; every stoppage involves the company in serious loss. For this reason the operative cannot be allowed to leave his work to discuss any matter with the supervisor unless the subject is one of great urgency. Thus all kinds of details which are, in reality, of a purely technical nature and which fall within the executive relationships of the foreman to those under his control become the subject of discussion between the supervisor and the shop steward who, by nature of his representative function, has the right to interrupt his work when he considers it necessary. The operator then comes to look upon the shop steward, rather than the supervisor, as his " boss " and expects him to " stand up to " the foreman on his behalf, even when the matter is rightly one in which the foreman has proper executive authority. This is a situation in which the author frankly admits that much more needs to be done before a satisfactory solution is reached and he urges that more research be undertaken to achieve a clear understanding of the complexities of this dual relationship.

Human Relations and Technology

One of the most overworked clichés of mid-twentieth century England is that our scientific and technological progress have greatly outrun our power to develop good human relations. This is usually spoken of in connection with the fear of war in view of our great powers of destruction; but it might equally well be applied to our industrial situation. We are only dimly and very reluctantly beginning to realise that there is more to production than the invention of more and more wonderful machines. At long last, courses on human relations are being introduced as an integral part of the curriculum for technological qualifications and attempts are made to enable those who are destined to be in managerial positions in industry to get some insight into the complexities of socio-industrial relationships. The trouble is that at present we know so little what should be taught in such courses because so little is known of the nature of the human problem in industrial enterprises and so little of the art—or science—of management. This book can be recommended as a textbook for such a course, for it is a relief to read one which replaces the usual platitudinous banalities by a clear and searching analysis of the fundamental issues. The candour with which the author sets forth the problems with which he has been confronted in his own firm and the ways in which he has tried to solve them provide a vivid and stimulating case book. Whether every man faced with the same problems would have found it right to act in the same way is beside the point. The great value of this book is in its clear exposition of the complex structure of a business and the importance of a thorough and unemotional understanding of its nature if both economic success and harmonious human relations are to be achieved.

The Hirst Research Centre

The Wembley Research Laboratories of the General Electric Company are being reorganised into a research centre—to be known as the Hirst Research Centre—consisting of a number of autonomous research units operating side by side. This change is a logical corollary to the recent changes in management structure whereby the company's activities are organised in seven main operating groups, each of which is largely independent. In the research centre these groups will be able to have, under their own control, research units led by their own research managers. Thus the later stages of research and development and design will be brought under common management and it should be possible to speed up the exploitation of new discoveries.

CHANGES in the organisation of the G.E.C. Research Laboratories at Wembley, accompanied by an appropriate change in name, were announced recently by Mr. O. W. Humphreys, the company's director for research and technical development. The laboratories will function as a research centre in which a number of autonomous research units will be set up. Each research unit will be closely linked with one or more of the company's operating groups and all the units will share the same scientific, administrative and ancillary services.

This change is complementary to the recent reorganisation of G.E.C. activities into seven operating groups which are concerned, respectively, with engineering, electronics, domestic equipment, installation equipment, lighting and heating, " Osram," and radio and television. The idea is that the research centre will enable any group to have a research unit under its own control (with a research manager responsible to the group) but working side by side with the Central Research Laboratories and the other research units. Thus it is hoped to add the advantages of decentralisation to those that spring from close contact with the extensive research organisation already built up at Wembley. By having close control over its research unit an operating group should be able to exploit the results of research expeditiously.

To mark this fundamental change in policy the G.E.C. Research Laboratories at Wembley will be known, in future, as " The Hirst Research Centre "—a name which commemorates the late Lord Hirst who founded the company and, forty years ago, inaugurated the Wembley laboratories.

Two main research units are planned as a first step in the building up of the new research centre ; one or two research group laboratories will follow soon afterwards and others later on. The first of the main research units are the Central Research Laboratories and the Telecommunications and Engineering Research Laboratories.

Mr. V. J. Francis will be the deputy director in charge of the Central Research Laboratories which will be responsible for most of the more fundamental research programmes, whether on behalf of the company as a whole, the groups or subsidiaries. They will provide specialised scientific and technical services and advice to the whole of the Centre, and will ensure effective scientific liaison between all research units.

The Telecommunications and Engineering Research Laboratories will work primarily on behalf of the Telecommunications and Engineering Groups of the company and will also carry out fundamental researches in related fields. Mr. R. J. Clayton, the deputy director in charge of these laboratories, will also be responsible for the administration of the Centre.

The Central Research Laboratories and the Telecommunications and Engineering Laboratories will continue to act for groups which do not, for the time being, set up their own research units. The changeover will be gradual. When complete, the system will be so flexible that any one research unit in the Centre will be able to take on work for another unit by mutual agreement. The increased concentration of the Central Research Laboratories on long range research will ensure that the company stays in the forefront of technological achievement.

On a recent visit to the Wembley Laboratories we were shown some of the research work in progress. Our tour was designed to concentrate on a few of the company's activities which have involved substantial research and development effort during recent years and are now ready or almost ready to yield a return on investment. Some of this work is described below.

Semiconductors

Semiconductors provide a striking example of a project in which research and development expenditure represents a substantial investment in future prospects. As explained by Mr. Humphreys, the director of the Hirst Research Centre, work on semiconductors was started at Wembley about ten years ago and a total expenditure of about £2,500,000 was incurred in the laboratories and in the factory before production could be regarded as firmly established. Two years ago the company's " investment " was £500,000 ; last year it was considerably less and in

1961 it is expected that there will be a profit after paying the cost (about £400,000) of the current research and development programmes.

The Regrown Diffused Silicon Transistor.—A new process known as the "regrown diffusion" technique for the production of high-frequency silicon transistors has been evolved at the Research Laboratories. It gives prospects of being able to produce silicon transistors as economically as present germanium transistors.

The process consists of two separate operations. In the first, two blocks of silicon, one heavily doped with arsenic (*n*-type impurity) and another heavily doped with boron (*p*-type impurity) are melted and fused into a larger block of silicon lightly doped with arsenic. When the temperature is lowered the molten highly-doped silicon re-crystallises on the unmelted region to re-form a single crystal. The total amounts of the two impurities are arranged so that in the regrown region the arsenic predominates and results in *n*-type silicon. During the second stage of the process, which is a prolonged high temperature bake, some of the boron diffuses out of the regrown region to form a narrow *p*-type base region, which can be controlled at 0·0001in thickness or less.

The division of the process into two separate steps has resulted in simple apparatus (Fig. 1). At the same time, the characteristics of the device can be accurately

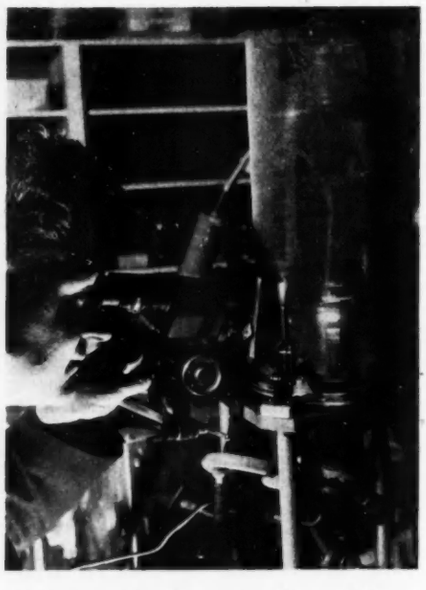


Fig. 1—Experimental apparatus for producing regrown diffused silicon crystals as used in high-frequency transistors

controlled. In addition, effective use is made of the standard singly-doped starting material.

The lower part of the *n-p-n* pyramid-shaped structure that is obtained by this technique can be cut up into bars of the dimensions required for each transistor. The first series of silicon transistors being produced in the factory by this method have typical cut-off frequencies in the range 20-30 Mc/s. The mechanical construction of these transistors has been designed to withstand the stringent environmental conditions met in guided weapons and similar applications. The characteristics are stable even when the devices are operated for long periods at temperatures up to 200 deg. Cent.

The Silicon-Controlled Rectifier.—Another interesting development in hand at these laboratories offers prospects for the production of a new silicon-controlled rectifier (S.C.R.) with an output of 50A at several hundred volts (Fig. 2). Briefly, the S.C.R. is as a small piece of silicon into which minute traces of impurities have been introduced to produce a *p-n-p-n* structure with each of the four layers carefully controlled in thickness and in impurity content. The outer *p* and *n* regions are known as anode and cathode respectively, and the central *p* region as the gate.

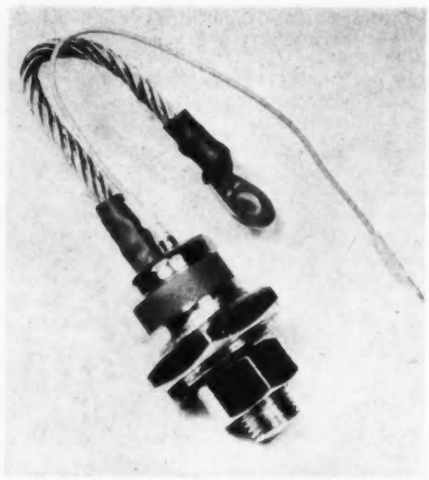


Fig. 2—A 50A silicon-controlled rectifier

Notable characteristics of the S.C.R. are (*a*) the very low voltage drop across it (about 1·2V) when it is in the low resistance condition ; (*b*) its ability to switch from a high resistance (forward) condition to a low resistance state in about 1 microsecond ; and (*c*) the gate current required to switch the device is very small (about 150mA for the 50A device). In addition, the S.C.R. is robust, reliable and easy to connect into circuits.

Typical uses of the S.C.R. range from fast circuit-breaking to voltage stabilisers ; from controlling the speed of electric motors to power inversion ; and from dimming theatre and studio lighting to controlled rectification. It can compete with power transistors in many low-voltage applications.

A Four-Layer Tetrode Switch.—The silicon-controlled rectifier has one disadvantage in common with the thyratron : it can be switched from a low-resistance to a high-resistance condition only by interrupting the anode voltage, or making it negative. In many applications it would be very useful to have a solid-state circuit element that could be switched both into, and out of, the low resistance ("On") condition by applying signals to control electrodes.

In these laboratories, work on the *n-p-n* "regrown diffused" transistor has been exploited to give such a circuit element. The requirement is a fast, *p-n-p-n* layer structure, with leads connected to all the layers. It has been found that the bar-type structure used in making the *n-p-n* transistor forms a good basis for the more elaborate structure.

The particular circuit element demonstrated during our tour of the laboratories can handle currents of some 50mA in its "On" state, with a volt drop of about 1·5V. The currents required to turn it "On" and "Off" are about 2mA. Switching times of the order of 0·2 microsecond can be achieved. The device can withstand voltages of about 45V and is therefore attractive for control circuits in low-voltage industrial applications. The high operating speed, coupled with the fact that the associated circuit is relatively simple, may interest designers of data-handling and computing equipment.

These new components are also important in providing another tool for studying conduction processes in four-layer *p-n-p-n* structures, including the controlled rectifier. Such studies should lead to improved performance in the structures. It is likely that the techniques used in making this particular circuit element may also be exploited to produce other kinds of solid-state electronic devices.

Radio Communications

The transmission department of the G.E.C. Telephone Works at Coventry has recently announced the completion of the first 6000 Mc/s broadband microwave radio system in the United Kingdom, with a capacity of 960 speech channels. Production for the British Post Office and overseas customers has already begun, and the first route is due to go into service in a few months. It will be the first application in this country of a number of new techniques and components. They include : (1) a replaceable 5W travelling-wave amplifier with periodic permanent magnet focusing (the only 6000 Mc/s valve used in the system) ; (2) A horn-paraboloid aerial of great frequency bandwidth ; and (3) new ferrite devices.

Travelling Wave Amplifier.—The TWC5 travelling wave amplifier was developed by the G.E.C. Valve Research Laboratory expressly for the difficult field of communications (as opposed to less exacting radar applications). It is now being produced at Hammersmith by the M.O. Valve Company, Ltd. The use of periodic magnetic focusing

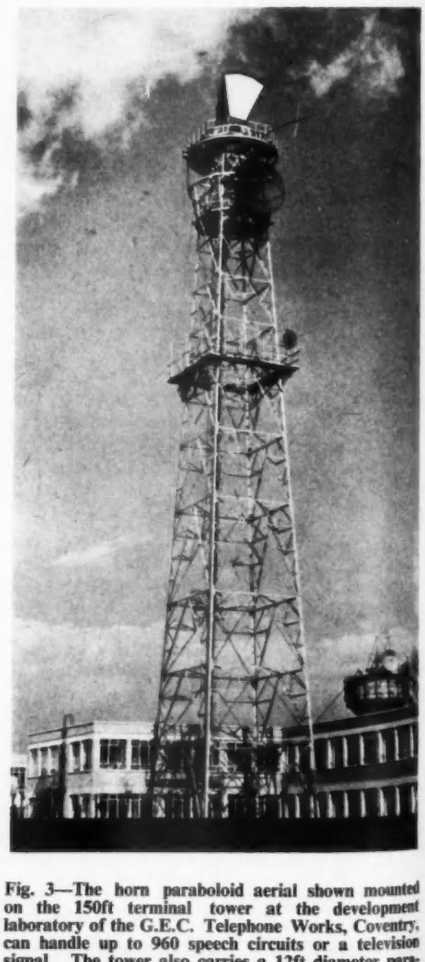


Fig. 3—The horn paraboloid aerial shown mounted on the 150ft terminal tower at the development laboratory of the G.E.C. Telephone Works, Coventry, can handle up to 960 speech circuits or a television signal. The tower also carries a 12ft diameter paraboloid for a 2000 Mc/s, 300 speech channel system

in the TWC5 gives reduced weight and low stray fields.

Horn-paraboloid Aerial.—The horn-paraboloid aerial is about 15ft high (Fig. 3) and, because of its size, was first studied in model form. Its bandwidth, impedance and radiation properties are superior to previous designs of aerial. It will not only enable a single aerial system to work with up to four transmitters and receivers in the 6000 Mc/s band, but it will also carry additional channels at 4000 Mc/s.

Ferrite Devices.—The microwave ferrite devices—a circulator and two types of isolator—were the outcome of materials research at these laboratories. The circulator, in particular, has greater frequency bandwidth and better performance than were previously available. It permits a simpler system of combining both transmitters and receivers on a common feeder and aerial, or multiplexing groups of transmitters or receivers. Furthermore, the problems of aligning individual parts of the system are greatly simplified when isolators are used.

Developments, like these, have enabled the G.E.C. to build a complete transmitter/receiver unit in a bay only 7ft 6in high and 8in deep—no larger than the 300-channel, 2000 Mc/s equipment already built in large numbers by the company.

Electronic Telephone Switching

Electronic telephone switching has been the subject of research work in these laboratories since the late 1940s. By 1955 the stage had been reached where a model electronic exchange, "Andrew," had established the basic feasibility of the time-division-multiplex technique as a basis for telephone switching; the conversations are switched and conveyed through the exchange in the form of short electrical pulses less than 1 microsecond in length; the height of the pulses is varied in sympathy with the speech signals to be transmitted.

The Highgate Wood Project.—In 1956 electronic switching research and development in this country became co-ordinated under the Joint Electronic Research Committee (J.E.R.C.), comprising representatives of the Post Office and five major manufacturers of exchange equipment. The committee decided that an experimental electronic exchange (the Highgate Wood project) should be designed and given a trial under public service conditions. This exchange is due to be put into service early next year.

The G.E.C., in collaboration with the Post Office, was made responsible for the design and manufacture of the time-division-multiplex speech switching network. The Wembley laboratories undertook much of the basic system and circuit design work in support of the development laboratories of the company's telephone works at Coventry.

It will be appreciated that the Highgate Wood exchange is only an experiment and the lessons which are being learned from its design and construction are being applied to the evolution of an exchange suitable for commercial exploitation. Recent work in the Wembley laboratories has therefore been concerned with system organisation and circuit work to follow the Highgate Wood project, with emphasis on system security and simplicity to keep down capital and maintenance costs, making full use of transistors.

The work of the electronic switching laboratories includes the design of models of a transistorised speech switching network and magnetostriction delay lines which are used for pulse generation and storage. Final engineering of the circuits for production is done in the development laboratories at Coventry.

Digital Computers

Thin Magnetic Film Stores.—Recent developments in computers emphasise the need for high-speed stores operating considerably faster than those at present available. Most existing machines use large numbers of small magnetic rings in the store and the maximum speed for this type of device allows the selection of up to 500,000 items per second.

The new thin magnetic film store offers an alternative system capable of being switched at about a thousand times this speed. In such a store, a film of magnetic material 5×10^{-6}in thick is deposited in a vacuum on a baseplate approximately 3in square. As it has two stable directions of magnetisation it can be used to store information in binary form. Two sets of parallel electrical conductors define a large number of very small areas, each capable of storing a separate bit of information; more than a thousand items may be stored on the surface of a single plate, and each can be switched in about 10^{-9} seconds. The cost of the magnetic film store is expected to be much less than that of existing stores using magnetic rings.

The 1301 Data Processing System.—Much of the original work on the central processing and immediate access store for the I.C.T. 1301 Data Processing System was done at the laboratories in association with Computer Developments, Ltd., a company jointly owned by G.E.C. and I.C.T. To prove the design, a computer (known as the 1301 "Test Bed") was constructed which consisted of the electronic circuits for the 1301, in conjunction with simplified input and output devices. This equipment, having served its original purpose, is now being used in a study of the problem of how to use a computer in the design of new computers. The main objective of the present study is to develop techniques which will enable an existing computer to provide complete design information on basic circuitry, printed board layouts, wiring instructions and overall cost.

Thermoelectric Cooling

Development of special semiconductor materials has now been carried to a point where some of them can be used for practical cooling systems based on the Peltier effect. For example, small pieces of bismuth-antimony-telluride arranged in the form of a rectangular block and connected together electrically, constitute a refrigerating system; when the assembly is connected to a direct-current supply one face of the block is cooled. Temperature differences up to about 140 deg. Fah. can be set up between opposite faces of the block. With somewhat lower temperature differences between these faces, cooling powers up to 15W can readily be achieved.

Such cooling systems have already been applied in scientific instruments and they have possibilities for general and domestic use. For example small cooling blocks have been used in instruments, for cooling a hygrometer mirror or for cooling components such as infra-red cells. They can also cool baffles placed in the throat of oil diffusion pumps to limit the spread of vapour. A cooling block, clamped between one face of a lagged metal box and a finned radiator, provides effective cooling for a small-capacity food container by maintaining an internal temperature of 45 deg. to 50 deg. Fah. inside the box for ambient temperatures of up to 90 deg. Fah.

Graphite for Nuclear Reactors

The Wembley Research Laboratories inherited a good background of carbon technology from the company's earlier interests in lighting carbons. After the war, the acquired experience was made available to the Ministry of Supply to help in the exploitation of nuclear energy and led to fruitful collaboration with the U.K. Atomic Energy Research Establishment when graphite became established as the moderator preferred for British power reactors.

Compatibility of Moderator and Coolant.—Research work has followed a familiar pattern in this field in that the reaction between graphite and the coolant gas was investigated outside the atomic pile before proceeding to work with irradiated materials. As a result of this work it is considered that the purely thermal reaction sets the limit to the operating temperature and efficiency of a gas cooled reactor. It has been shown that no significant corrosion hazards are reached below a temperature of at least 600 deg. Cent. Effort is now fully engaged on the last stage of this research where the reaction is studied within the pile. The Wembley Laboratories contribution in this field has been expanded and integrated with the U.K.A.E.A's activities. The Laboratories' substantial share in this programme is based on a very flexible irradiation test whereby the graphite specimens are encapsulated in quartz before irradiation. Many different reactors can be used for tests of this kind and it has been found possible to rationalise the results from the widely differing irradiation facilities. Over a thousand irradiation experiments of this kind have been completed.

The results have helped to establish the events leading from the absorption of radiant energy in the gas to the decomposition of the carbon dioxide, to the transport of the corrosive fragments to the carbon surface and finally to the gasification of the moderator. For instance, the Authority's findings that the gas within the pores of the graphite is mainly responsible for gasification have been confirmed. A particularly interesting life test lasting about a year has been completed in the "BEPO" reactor. The behaviour of the graphite in irradiated carbon dioxide has been regularly monitored by electrical measurements.

Mechanical Behaviour of Moderator in the Reactor.—The mechanical properties of graphite have been studied at the Research Laboratories for about ten years. Work on the elastic and plastic properties of graphite at very high temperatures (1300 deg. to 2000 deg. Cent.) provided a good fundamental understanding of graphite as a structural material. Measurements on pre-irradiated graphites show that the strength is markedly improved by irradiation. These irradiation-induced changes of the mechanical properties proved encouraging from the engineer's point of view, but there was the possibility that irradiation might cause a relaxation of stress that would be apparent as creep. An extensive experimental study within the framework of the U.K.A.E.A.'s graphite programme has been undertaken.

The laboratories have been the first to demonstrate the existence of "irradiation creep" in graphite and to confirm it with about a thousand irradiation experiments. A preliminary lack of relationship between creep and irradiation temperature has been established. Creep arises from carbon atoms which are temporarily displaced by energetic neutrons during irradiation and not from those which are found out of their positions after irradiation. It is shown that events occurring during irradiation

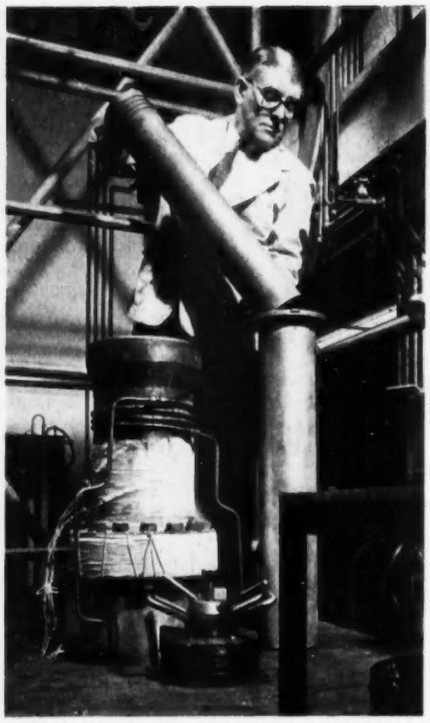


Fig. 4—A graphite tube for a nuclear fuel element is carefully inserted into a protective steel casing before being lowered into the special equipment for high-pressure impregnation and curing

cannot always be judged by the permanent changes in physical properties. The effect of such an irradiation creep helps to compensate for the normally brittle nature of graphite in that it provides a welcome relief for the stresses which build up within a graphite block as it undergoes irradiation.

Impregnated Graphite.—The G.E.C. design of reactor involves a graphite fuel element sleeve. This sleeve can be used to give independent control of coolant flow rates over the fuel and moderator and so prevent uncontrolled release of Wigner stored energy. For this purpose the permeability of the graphite sleeves can be reduced by several orders of magnitude (e.g. 10^6) by a sugar-impregnation process (Fig. 4) invented at the laboratories. It underwent test-tube trials in November, 1957, and the production plant for the treatment of 1000 sleeves a week was commissioned early in 1960. The process could have other important applications in the chemical, metallurgical and nuclear industries. A laboratory pilot plant is supplying material to test and explore these possibilities.

Impermeable Carbon.—Another development sponsored by the laboratories is more speculative and is aimed at the next stage of nuclear power generation. Since graphite has a very high melting point, a very small neutron absorption and excellent thermal conductivity, it would be an outstanding "canning" material if it could be produced in impermeable form. The level of impermeability required precluded the use of impregnation techniques.

Studies of the accessibility of gases to the inner surface of different carbons suggested that a carbon sleeve could be made with a permeability low enough to ensure the encapsulation of the fission product gases inside the sleeve. A novel process was devised to overcome the fundamental problem of carbonising a solid body and expelling half its weight as gas through pores which later must be closed to ensure impermeability. Several years' work on a pilot plant have brought this idea to reality. Carbon tubes as impermeable as quartz can now be shrunk-fitted on to fuel shapes. This process has the further advantage that control of the gap between fuel and can need no longer be paid for by expensive grinding and machining processes.

Lamps

The "Osram" Group of the G.E.C. maintains a large team of scientists at the Research Laboratories to make fundamental investigations into every aspect of light production. In addition to light sources the work comprises research on metals, glass and phosphors used in the lamp field. Its primary concern is with basic and feasibility studies on existing and new light sources.

Progress in Sodium Vapour Lamps.—Studies in the Research Laboratories promise very high luminous efficiencies in sodium vapour lamps. Experimental lamps, with a new kind of heat conserving sleeve around the lamp, operate with an efficiency of 130 lumens per watt. There is good indication that even higher efficiencies will be obtained in the future.

Heat conserving sleeves were first used in the robust "Integral" design of lamp developed in these laboratories in 1955 to replace the "Dewar" jacket type of lamp in use since 1932. The 140W lamp had an efficiency of 80 lumens per watt compared with the 73 lumens per watt of the older type and was more reliable. The efficiency was raised later to 100 lumens per watt in a 200W "Linear" lamp using the "Integral" principle.

Attention was then turned to the use of transparent heat reflecting metallic films on the sleeves, and in particular to the use of very thin films of gold. These films have enabled the further improvement in efficiency to 130 lumens per watt to be made in experimental lamps, as mentioned above.

High-Pressure Sodium-Vapour Lamps.—The work has shown that, contrary to generally accepted views, above a certain vapour pressure of sodium not only is high luminous efficiency possible, but a useful change in the spectral distribution of the light takes place, giving an improved colour. The intense chemical activity of the sodium vapour in these conditions demands a more refractory and highly sodium-resistant glass than is at present available. Current research indicates that suitable materials can be developed.

Iodine in Tungsten Filament Lamps.—The life of a tungsten filament lamp depends largely on the rate at which tungsten evaporates from the incandescent filament. If evaporation can be reduced the lamp will live longer, and if the evaporated tungsten can be prevented from reaching the wall of the lamp the bulb size can be reduced without risk of blackening during life.

These goals have been reached by adding a small quantity of iodine vapour to the usual gas filling of the lamp. Provided the temperature of the wall of the bulb is high enough—a condition requiring the use of a very small quartz bulb—the iodine reacts with the evaporated tungsten before it reaches the wall; tungsten iodide is formed is formed and is decomposed again into tungsten and iodine, near the incandescent filament, in a cyclic chemical reaction which confines the evaporated tungsten to the region of the filament.

High-powered lamps of very small size, with lives up to double those obtained in conventional designs, and almost perfect light maintenance, are made possible by this new advance. The need for very high bulb temperatures prevents the use of the new lamps for domestic lighting. Their most probable early applications will be to ciné projectors, sports-field floodlighting and aerodrome lighting, with additional uses as the ballast components for high-pressure mercury-vapour fluorescent lamps.

Combined HPMV-Tungsten Filament Lamp.—The advantages of very small bulb size, long life and maintenance of luminous output, offered by the iodine vapour effect in tungsten filament lamps, have been utilised in an experimental high-pressure mercury-vapour lamp which operates directly from normal electrical supplies without the usual stabilising choke and power factor correcting capacitor. Such a lamp, of 450W rating, contains a 250W quartz high-pressure mercury-vapour discharge lamp together with a 200W tungsten-filament lamp in a very small tubular quartz envelope, with iodine additive. The two sources are mounted close together in the same phosphor coated jacket. The light blending of the two sources is excellent. The luminous efficiency of the experimental 450W lamp is 60 per cent greater than that of a normal tungsten lamp of the same rating and its life is four times that of the filament lamp. This performance is significantly better than that obtainable with the filament freely mounted in the fluorescent outer envelope.

Lighting

The Illumination Group is concerned with the application of light, and with the engineering of lighting equipment to use lamps to meet the needs of people over an extremely wide range of activities. The task begins with establishing in detail what the visual requirements are and what mechanisms of seeing are involved. It includes the design and testing of lighting equipment, for photometric, mechanical and thermal performance. In the more complex problems the design of the whole scheme is carried out in collaboration with the commercial lighting engineers at Head Office or the branch concerned.

Special Test Equipment for Street Lighting.—Lighting equipment is developed and tested in a laboratory equipped for the investigation of light distributions by means of apparatus with rotating mirrors. In effect these mirrors cause a photocell at a distance to revolve around the fitting. Equipment which is too large for the mirrors demands a cell which moves round a large circular track, stopping automatically at the required angles.

Much of this work centres on equipment for street lighting, which requires a very nice control of the light distribution if installations can be realised which are economical, yet free from glare and patchiness, on the modern non-skid road surfaces which are much less helpful than those used before the war.

Driving Studies.—The requirements of drivers have been studied recently in a series of experiments made on a new basis, which involved taking films and tape recordings while driving. It has been established that on traffic routes in towns, lighted to modern standards, the information which drivers receive at night is usually sufficient, though there are some weak spots. On the motorway, however, the requirements are very different. Headlights alone are quite unable to give adequate information to the driver. It has been found that there are sound reasons, from the point of view of visual safety, for lighting the motorways by fixed lighting.

SHORTER REPORTS

Duke of Edinburgh to Deliver Graham Clark Lecture

THE Duke of Edinburgh will deliver the Graham Clark lecture in London on April 13, it was announced last Friday from Buckingham Palace. He will be addressing a joint meeting of the three major engineering Institutions—the "Civils," "Mechanicals," and "Electricals." His subject is "Resources, Human and Material, of the Commonwealth." The lecture is to be delivered in the Great Hall of the Institution of Civil Engineers. The Duke will be the first member of a the Royal Family to speak at the Institution. The lecture has been held annually, in turn at the three Instiutions, since its inception in 1955. It is named after the late Mr. Graham Clark, secretary of the Institution of Civil Engineers: he strove for closer collaboration between engineers.

Conference on Satellite Launcher Development

THE British and French Governments are convening an international Conference to begin at Strasbourg on January 30, to consider co-operation between European and Commonwealth countries on the development of a heavy satellite launcher. The object of the Conference will be to study the technical and financial possibilities of international co-operation with a view to the development of a satellite launcher utilising the rocket "Blue Streak," capable of putting heavy satellites into orbit, and the development of a first series of satellite test vehicles as a preliminary to the possible exploitation of satellites for various uses. The British and French Governments have not yet themselves taken any decision to undertake the development of these equipments. They wish, however, to discuss the desirability and possibility of doing so in conjunction with other interested Governments. The co-operative venture envisaged would not be concerned in any way with the military use of lanchers or satellites.

The scope of this co-operation would complement but overlap the activities of the projected European Space Research Organisation. Joint invitations to the Conference have been issued to the following European countries: Belgium, Denmark, the Federal German Republic, The Netherlands, Italy, Norway, Spain, Sweden, Switzerland and Austria. During the past week representatives from ten European countries have been meeting in London to discuss the technical aspects of a launcher programme. They have been given an outline of the work already carried out in the United Kingdom and talks have been held on the additional work that would be needed to develop launcher vehicles.

Mr. Thorneycroft, the Minister of Aviation, will be the chief British representative at the Strasbourg Conference. He has already had exploratory discussions with many of the Governments which have been invited. Recently he visited the Federal German Republic, Denmark and Norway. He is also visiting Italy and Switzerland.

Hydrology of the River Severn

THE second of the hydrological surveys of British rivers, undertaken by the Surface Water Survey of the Ministry of Housing and Local Government, relates to the Severn catchment, which is the largest in the British Isles. The survey is published by H.M. Stationery Office*. The first of these surveys related to the Great Ouse.

The Severn survey is in three parts. Part I consists of four general sections dealing with the area and population, hydrology, rainfall and hydrogeology of the basin. Part II describes in greater detail the position in the five sections into which the basin has been divided, and in each section there are tables showing abstractions and returns of water and a water use balance sheet. Part III comprises a summary, bibliography, and water use balance sheet for the river basin as a whole.

The survey points out that river gauging data are still lacking in many parts of the Severn basin and it is important that the proposed additional gauging stations, mentioned in various sections of the report, should be established as soon as possible. The water in the rivers of this hydrometric area is on the whole of good quality and, save for three or four major discharges, the effects of polluting effluents tend to be fairly local. Schemes for the improvement of most of the discharges of any significance are in progress and many of them will be completed and effective within the next two or three years. Nevertheless the amelioration of conditions produced by several of the major discharges is likely to take longer, and this applies in particular to the condition of the Worcestershire Stour and to a modified extent to the River Avon.

The mean run-off is of the order of 2200 m.g.d. From a hydrological point of view the resources of the basin are capable of development, but each additional development tends to become more expensive in relation to the amount of water made available. The point has about been reached in the River Severn basin where no more water can be taken without a properly organised plan.

At the present time the river basin supports a water use amounting to 121 m.g.d. within the area and exports 43 m.g.d. without serious consequences as to quantity or quality even during prolonged periods of dry weather. It might be that a further 10 m.g.d. could be taken from the river without very noticeable effects even during a drought; it is evident that a further 50 m.g.d. could not be taken without producing serious difficulties in dry weather, and that a further 100 m.g.d. might occasionally dry the river above Bewdley and would certainly produce very objectionable conditions lower down the river.

Proposals have already been made by public water undertakings to construct works as quickly as possible capable of abstracting an additional 100 m.g.d. (approximately), so that by the mid-1960s total abstractions could amount to say 260 m.g.d. These figures make no allowance for increased direct abstraction by industry or for irrigation. Other undertakings have said that they will eventually have to draw water from the river, and current experience suggests that the use of water for all purposes is expanding rapidly. Long term estimates must necessarily be speculative but by 1980 the internal use of water may have increased to 170 m.g.d., exports by 200 m.g.d. and possibly 64,000 acres of crops might be irrigated in dry years.

Storage will be necessary to meet both the known demand and the possible future increases. The survey examines in broad principle the ways in which storage might be provided. The methods examined include regulating reservoirs, pumped storage, and conventional reservoirs. It is pointed out that the terms under which reservoirs were operated would need to be reviewed as demand increased, and that the developments envisaged in the report could be greatly expanded should the need arise.

* *River Severn Basin Hydrological Survey, Hydrometric Area No. 54.* Price 17s. 6d.

Midland Motorway Links

MR. ERNEST MARPLES, Minister of Transport, has announced "the making of the scheme fixing the route" of the first section of the Midland motorway from Castle Bromwich in Warwickshire to Dunston in Staffordshire, a distance of 25½ miles. The Ministry describes this as "the first major step towards the construction of motorway link roads to connect three national motorways with one another in the Birmingham area, and to provide access to these motorways from the Midland industrial areas."

Proposals have already been published for another link road to run from Lydiate Ash to join the Castle Bromwich-Dunston road at Great Barr, so providing a connection between the Bristol-Birmingham and the Birmingham-Preston motorways. A draft scheme will be published later for a further link road between Castle Bromwich and Catthorpe, which is on the route of the next stage of the London-Yorkshire motorway.

The new Castle Bromwich-Dunston route follows the line of the draft scheme published in December 1959. The rest of the published line between Coleshill and Castle Bromwich has not been confirmed, because of "special difficulties which have been met in settling the line in the Coleshill area."

Award of James Watt Medal

THE Council of The Institution of Mechanical Engineers has awarded the 1961 James Watt International Medal to Professor Dr. Theodore von Kârman, Ph.D., in recognition of his important contributions to the advancement of mechanical engineering science, which have extended the frontiers of engineering knowledge particularly in the field of aeronautics. The nomination of Professor von Kârman for this award was sponsored by the American Society of Mechanical Engineers. It is hoped that the presentation of the medal will take place at a meeting of the Institution later in the year. The James Watt International Medal was founded to commemorate the bicentenary of the birth of James Watt, which took place on January 19, 1736.

Racing Tyre Recognised

THE Ferodo Gold Trophy for the most outstanding British Commonwealth contribution to the sport of motor-car racing has been awarded for 1960 to the Dunlop Rubber Company, Ltd., whose racing tyres were fitted to all the winning cars in all the *grandes epreuves*. The "R5" tyre is credited with effecting about half of an improvement in lap times amounting to as much as 6 m.p.h. at Silverstone (won in 1959 and 1960 by Brabham in a Cooper-Climax, at 102·7 m.p.h. and 108·7 m.p.h.). This improvement was effected in the road-holding qualities, due partly to the low-profile design with a wide flat tread and flexible side-walls, and partly to a new high-friction tread compound. The speed performance was also increased, up to 180 m.p.h. being allowed at Monza. (The combination of high friction and a limited speed suggests that the tread is of high-hysteresis butyl rubber). The tyre life was adequate to complete all races without tyre changes, with the exception of Monza.

Symposium on Industrial Vacuum Plant

THE Institution of Mechanical Engineers has issued details of a symposium on user experience of large-scale industrial vacuum plant, which is to be held in London on March 1 and 2, under the joint auspices of the Institution and the Joint British Committee for Vacuum Science and Technology. The provisional list of papers ranges over a wide field including metallurgical, aerodynamic, nuclear, medical, veterinary and food processing applications. Full details are obtainable from the Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1.

SHORTER REPORTS *(Continued)*

Simulator for Nuclear Power Stations

AN analogue computer specially designed to simulate the behaviour of a complete nuclear power station has been developed by the Precision Engineering Division of Short Brothers and Harland, Ltd., Belfast. This instrument is being built for the United Kingdom Atomic Energy Authority for use in the Calder Operations School. It will help a trainee, before he goes to work in an actual nuclear power station, to attain proficiency in the control of reactors, and to handle emergencies such as the development of instabilities in the reactor, variations in electrical demand, or failure of a heat exchanger.

The Short simulator will consist of a console and five racks of equipment, to represent a reactor which, for this purpose is considered as being split into three zones. The nucleonic and core heat transfer simulation units for each particular zone are each mounted in a standard Post Office type rack about 7ft high. Thus three of the simulator's five racks are identical, an arrangement which has the advantage that simulation of any further splitting of the core would necessitate only the installation of more standard racks.

The fourth and fifth racks house the equipment for reproducing the behaviour of the heat exchangers, steam production and flow, and the generator units. Information will be supplied to the instruments on fuel cartridge irradiation, inlet and outlet temperatures of the gas, steam pressures and rate of flow, position of the control rods, turbine speeds, and electrical power output.

A mock reactor control desk similar to those being supplied to new power stations is being designed by the U.K.A.E.A. Research and Development Group for use with the Short simulator. The instruments on the desk will receive their information from the simulator, which will also interpret any control adjustments made by the trainee operator and revise its signals to the desk instruments accordingly. Thus the trainee operator will receive his instruction at a control desk which, as far as the evidence of his senses is concerned, is directing the activities of a full scale nuclear power station.

The simulator will incorporate many of the facilities devised for the new Short "Simlac" multi-unit computer, including push-button control and automatic checking. The overall component error will not exceed one part in 1000.

With its removable patch panel the simulator is accommodated in the console which also acts as a junction box for the interconnection of the three reactor zones and the heat-exchange turbo-alternator group. In this flexible arrangement the addition of further zones involves only the laying of an extra cable up to the console, the original equipment remaining undisturbed. The power units are also housed in this console ; they are fully transistorised and dissipate very little heat. The racks (three on one side and two on the other) are installed at right angles to the console, the plan view of the installation being roughly "U"-shaped, and the control desk is placed immediately in front of the console.

Although the U.K.A.E.A. is supplying its own control desk for the Calder simulator, the company can offer a complete, self-contained system employing a Short-built replica of the standard desk. Thus it should be possible to train competent operators even in areas where there are no existing atomic power installations.

A point of interest is that a relatively small modification in the basic machine will convert it from simulation of the Calder Hall type of reactor to that of advanced gas-cooled reactors. Accordingly the simulator could be utilised in regions without atomic power before the authorities concerned had made a final decision about the kind of reactor they would require.

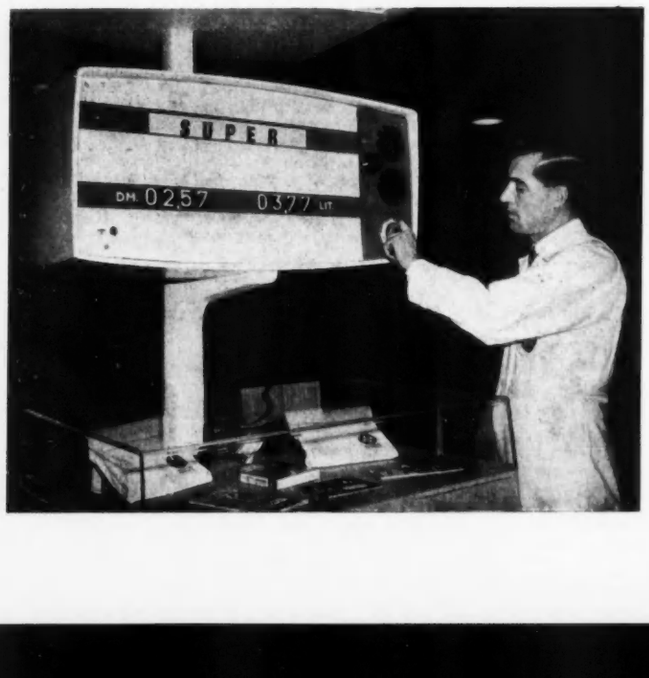
[Reply Card No. E1361]

Fuel Dispensing System

A NEW system for dispensing fuels, the "Autovista" designed by the British Petroleum Company, Ltd., and developed in collaboration with the De Havilland Engine Company, Ltd., is expected to be installed within three months at BP filling stations in Italy and in the United Kingdom. Basically, the "Autovista" system separates the two main functions of the conventional petrol pump—the hose through which fuel is pumped into the tank and the dial settings for the amount of fuel required—into two distinct units. The dials are positioned in front of the space where the car pulls up, whilst the hose unit is set some feet behind. By presetting the dials on the control panel, various grades of fuel can be dispensed from the one hose unit. The dials can also be preset so that the hose unit will deliver petrol to the value of a particular sum of money, or for any required volume. It is claimed that the new system will effect a saving in the time needed for each transaction, and by obviating the necessity for a central island containing a battery of pumps, will allow the designers of filling stations much greater scope in their layout.

The selector switch, which can be seen on the control panel in the illustration we reproduce, enables the operator to preselect the required grade of motor spirit. The movement of this selector switch initially rotates the grade panel to show the correct grade selected and it is this rotation that operates the actual grade selection, thus making it impossible for the incorrect grade to be shown in the event of an electrical fault. After this selection and the further selection of the required volume or price presetting, the removal of the trigger nozzle of the hose unit from its holster initiates the necessary valve settings and the starting of the motor to drive the appropriate pump. The positioning of the hydraulic system, the electronic control system, the money and volume dials, and the selector panel, is flexible as the only connections between them are multiple electric cables.

The rotation of the flow meter spindle is used to generate two trains of electric pulses by means of photo-electric scanners which read units of price and units of volume independently. These two pulse streams are then led through electronic circuits which reform the pulse shape and amplify them. From there the pulses are fed into separate channels which control the volume indicator and the total price indicator. When the totals shown on the meters near the preset totals the closing of the valves is initiated, and they are finally closed when the totals coincide.



"Autovista" control panel calibrated in litres

Rapid Reconstruction in a Steel Works

IN the summer of 1960, William Beardmore and Co., Ltd., decided to adopt a revised method of casting stainless steel ingots and steel sections for forging at its Parkhead Works, Glasgow. It was essential that steel production should suffer a minimum of interruption and this was the controlling factor in a contract for reconstruction, which was carried out by the Brydon Construction Company.

The work consisted of levelling and fine grading 20,000 square feet of the floor of the existing casting shop, constructing a forge ingot pit 90ft by 15ft by 15ft deep, a light forge ingot pit 81ft by 10ft by 10ft deep, a mill ingot pit 116ft by 8ft by 8ft deep and a mill ingot pit 220ft by 9ft by 7ft deep, all in reinforced concrete and bottom-lined with firebrick. The walls were lined with steel plates by the client, but this involved positioning over 600 heavy bolts in the shuttering.

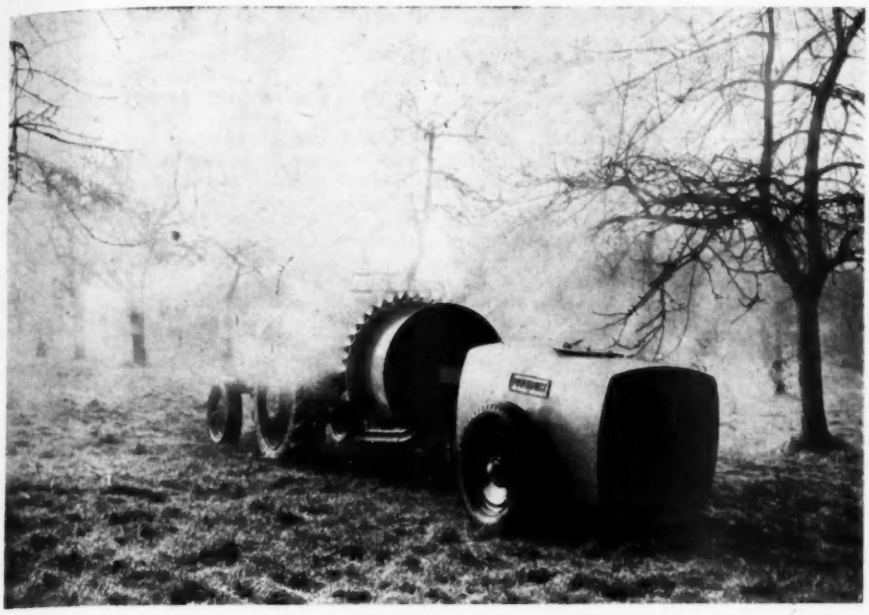
Over 3000 cubic yards of excavation had to be removed. A large proportion of it was in old concrete and brickwork foundations, intermingled with steel sections and slag, and the use of explosives and compressed air and burning equipment proved essential. All of the pits were close to the foundations of building columns supporting heavy overhead cranes.

The pits were designed by the contractor as far as the reinforced concrete work was concerned. Over 1200 cubic yards of concrete was placed. The design required something in the nature of 30 square feet of shuttering per cubic yard of concrete. Shuttering was prefabricated using the company's patented steel shuttering and was placed with a tolerance of plus or minus $\frac{1}{4}$in.

The site was handed over by the client at mid-day, December 31, and handed back to him in time to start full operations at 2.00 p.m. on Tuesday, January 17, a total construction time of seventeen days. The contract was a fixed-price lump-sum contract.

International Course in Hydraulic Engineering

The 1961–62 post-graduate International Course in Hydraulic Engineering at Delft will commence on October 19, and terminate on September 14, 1962. Those interested should apply before July 31 to : Netherlands Universities Foundation for International Co-operation, 27, Molenstraat, The Hague.



"Powermist Major" sprayer at work in a Kent orchard

Tractor-Mounted Sprayer

THE new "Powermist Major" tractor-mounted sprayer made by Kent Engineering and Foundry, Ltd., Maidstone, has been designed principally for use in orchards and hop fields. Driven from the power take-off of the tractor, the machine incorporates a twin-cylinder pump, mounted directly on the gearbox, which is capable of delivering from 20 to 500 gallons per acre at tractor speeds of from 1½ to 3 m.p.h. The liquid to be sprayed is ejected through twenty "Supercon" hardened steel nozzles into the side of an air stream created by the multi-blade axial flow fan. Power from the p.t.o. is transmitted from the gearbox to the fan through a centrifugal coupling. Mounted on a Ferguson "65" or Fordson "Power Major" tractor, the fan of the sprayer produces 35,000 cubic feet per minute of air at 110 m.p.h., and is capable of displacing the air in the tree as it passes and replacing it with insecticide-laden air. On a calm day, when the air is fairly still, it is claimed that the sprayed liquid will reach the top of a 50ft tree.

The trailer tank, which is usually of 200 gallons capacity, is fitted with mechanical agitators, and is attached to the frame by a special spring-loaded "quick-hitch." The tyres are 6·00×19.

Two models of the "Powermist Major" are available, the "Super" having a 30 g.p.m. high-pressure pump and twenty "Supercon" nozzles, whilst the standard machine has a 14 g.p.m. medium pressure diaphragm pump and ten "Supercon" nozzles. Nozzles are available in three different sizes. The machine will fit most makes of tractor having normal three-point linkage and power take-off.

[Reply Card No. E1371]

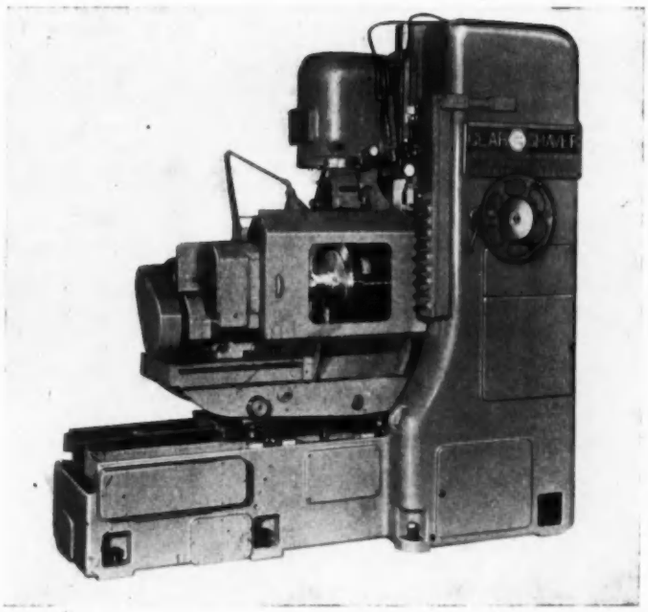
Gear Shaving Machine

A GEAR shaving machine of "tunnel" design added to the "Red Ring" range made by Precision Gear Machines and Tools, Ltd., Bodmin Road, Coventry, is stated to have the advantages of a column machine without in any way restricting the method of vertical loading and unloading heavy components. It takes gears from 3in to 24in pitch diameter and 25½in outside diameter having from 2in to 16in diametral pitch. Cutters of 12in pitch diameter can be used on the machine, the centre distance available between cutter and work being from 5in to 19·5in.

In this machine, illustrated herewith, the heavy cast iron column straddles the 72in long reciprocating table which carries a power driven headstock and a tailstock adjustable to admit work up to 36·5in between centres. The column houses the cutter head, vertical and transverse feed assembly.

In the gear shaving cycle the work and cutter are run tightly in mesh whilst the component is reciprocated across the cutter face. In single increments the cutter is automatically fed into the work and the work gear rotation reversed at the end of each table stroke. At the end of the preselected number of strokes the cutter is raised rapidly to clear the work and the table moved in rapid traverse out to the loading position. It is stated that as the cutter is driven by the heavier work-gear on this machine no undue stress is imposed on the cutter teeth by rapid reversal of rotation at each table stroke.

[Reply Card No. E1372]



Shaving machine for gears from 3in to 24in pitch diameter

Engine-Driven Cleaning Spray

A CONVENIENT alternative to steam cleaning plant is to be manufactured under licence in this country by Opancol, Ltd., 20–21, Tooks Court, Cursitor Street, London, E.C.4, under the designation "Kleen Gun." This device uses not pure steam but the exhaust from a positive-displacement internal combustion engine, consisting essentially of steam mixed with nitrogen, oxygen, and carbon dioxide; the engine, if not loaded in any other way, will in general be capable of delivering at 150 lb to 200 lb per square inch. The hot gases are expanded through an ejector which draws in cleaning fluid through a plastics pipe, and the resulting blast is described as capable of removing caked grease or mud. An advantage over classical steam cleaning is that, if the work is rendered hot, it finishes dry and ready for painting. The "Kleen Gun" has an adaptor which fits exhaust pipes of various sizes, and the 14ft long gas hose is of stainless steel. The sprayer is expected to run satisfactorily off any engine exceeding 2–2½ litres; in the case of large

"Kleen Gun" running off an agricultural tractor; the engine is a diesel with a distributor fuel pump

low-speed engines it should be borne in mind that the pressure in the exhaust manifold may be sufficient to open the exhaust valves. Two grades of cleaning compound are offered, No. 2 being capable of degreasing without damaging paint, while No. 3 is caustic and strips paint.

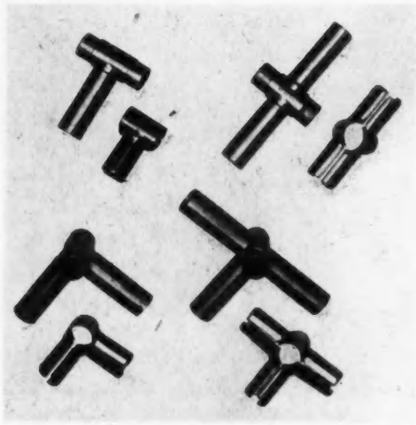
It is also possible to feed fuel to the gun, and, using a flame holder which is available, employ it as a flame-thrower with a flame adjustable between 2ft and 12ft long; this application is envisaged for agricultural purposes such as clearing unwanted growth, burning out fire-breaks, or sterilising animal quarters.

[Reply Card No. E1373]

SHORTER REPORTS *(Continued)*

Joints for Tubular Structures

A NEW design of joint has been developed by Access Equipment, Ltd., Maylands Avenue, Hemel Hempstead, Herts, for the quick and easy assembly of tubular structures with simple tools and without the use of welding, bolting or screwing of any kind. These "Clinch" joints are made in a number of forms to cover a wide field of structural requirements. Four forms of the joint are shown in our illustration and the



Four typical tube joints and their application in tubular structural assemblies

basic principle of the design is best seen in the straightforward single tee joint to be seen in the top left-hand corner of the photograph.

This single tee joint consists essentially of a piece of steel having a central rounded section which is slit and has depending from it a spigot comprising two curved " legs " which are sprung apart. In assembling a structure the rounded section freely admits the cross tube of the tee and when the legs are then closed together to grip the tube—using a special pair of grips—their tapered outside surfaces provide an initial push fit into the bore of the stem tube of the tee. When the grips are removed the stem tube is driven right down the legs by hammering on a spigoted mandrel inserted on its free end. A rigid hold is thus provided on the cross tube by the closing in of the rounded central section of the joint and the wedging effect of the stem tube driven over the legs.

Two-, three- and four-piece joints based upon the same principle are supplied for assembling structures with tee cross, double tee, right angled and double- and single-cross connections. At present these joints are made in one standard size for use with the 1¼in o.d. 16 S.W.G. welded steel tubing supplied by the firm: we are informed that the range will later be extended to cover ¾in, 1in and 2in diameter tubes.

An extensive selection of racks, stillages, bars, benches and other tubular structures have been made with the joints, and interesting tests have been carried out to show the capacity of a standard single-tee 1¼in joint. It was found that a tensile load of up to 500 lb could be applied to one end of the joint on the cross tube before it started slipping down the tube. With the joint on the cross tube supported from points on either side a load of 2000 lb was applied to the stem tube before it began to slip off the joint legs. If required, users can apply the joints to their own tubing which, to give efficient performance, should have an outside diameter tolerance of ±0·005in and be of 16 S.W.G. with a tolerance of ±0·004in.

[Reply Card No. E1381]

Automatic Test Equipment

APPARATUS for carrying out long test sequences on electronic equipment, electro-mechanical systems and items such as complex cableforms was demonstrated recently by the Automatic Test Equipment Division of Elliott Brothers (London), Ltd. This division, located at Airport Works, Rochester, Kent, has developed a switching technique using " Ledex " multi-wafer rotary switches for the separate functions of programming and setting up the test circuits. The combinations available are more flexible than can be obtained with uniselectors, and the principle of using all components as many times as possible is followed in order to cut down the size of the equipment. The console illustrated was originally designed for the complete check-out, testing and servicing of an auto-pilot system. One pedestal contains an hydraulic plant capable of simultaneous operation of four actuators, and this section can be adapted for testing other forms of hydraulic system.

The right-hand pedestal contains the electronics, controlled from the panel on the upper facia. Operation of a single selector switch steps the programmer, which in turn controls the secondary selectors. A meter shows by slight movement to right or left of a central position whether the test result is within the percentage allowable. Simultaneously the test number is shown on three display tubes on the panel. A telephone dial alongside the indicator enables any test to be selected, or the whole sequence can be worked through by operating the selector switch. In its present state of development the equipment caters for a total of 350 individual tests, and can test a combination of units, or units and sub-units singly, up to a maximum of thirty-three.

An extension of the above principles was demonstrated in a programmed automatic circuit-checking equipment, also using " Ledex " switches. This operates from instructions on a 1in magnetic tape. The apparatus will carry out resistance, continuity, and insulation tests between lines and to earth with up to 600 terminations. Each termination is checked against every other termination. The number of possible combinations with 600 terminations is 180,300. Only 120in of tape are needed to accommodate all possible programme material.

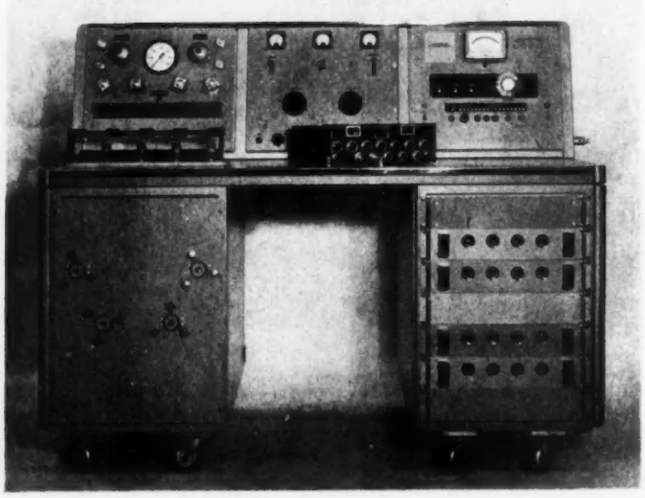
Several forms of counter are included among the products of this Elliott division, and among examples shown was an automatic ream-counter for counting sheets of paper as they are cut from the bulk reels. An electromechanical counter is actuated by impulses fed from a microswitch attached to the fly knife shaft, and causes illumination of edge-lit numerals. Provision is made for marking or spraying sheets at predetermined intervals during the count, the marks being visible when the sheets are stacked, indicating a set number of sheets between them.

[Reply Card No. E1382]

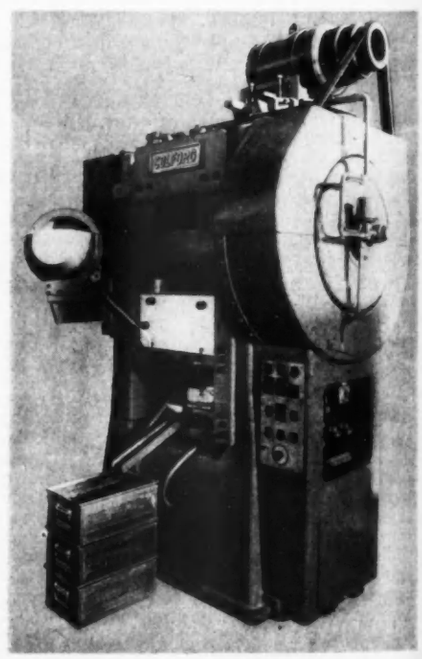
Cold Forging Press

A MECHANICAL press designed and built for cold forging steel components made by Cold Forging, Ltd., Camp Bird House, Dover Street, London, W.1, is capable of exerting a working pressure of 200 tons at 30 deg. before reaching bottom dead centre. It can be fitted with interchangeable multiple tool units which can be made to enable up to six forging operations to be carried out on each working stroke. These tool units—each for parts of different size, shape and weight—can be stocked in a preset form and quickly interchanged when required.

The press, illustrated on this page, has a welded steel frame of sections, held together by four vertical prestressed tie rods, and braced internally against lateral deflection. Long guides extend from below the working plane of the tools to above the level of the pivot point of the connecting-rod. A 20 h.p. motor drives the flywheel through a three-speed vee belt arrangement giving stroking rates of 60, 75 and 90 per



Test console for servicing electronic and electro-mechanical systems



Cold forging press fitted with a tool for nut production and having an automatic feed mechanism

minute. A pneumatic-cylinder-operated, spring-release clutch engages the drive to the crankshaft at the front end, and at the rear end is a spring-operated, air-released brake. The clutch and the brake are electrically interconnected to stop the machine in the event of failure of the compressed air supply or equipment. From the clutch the drive is transmitted to the crankshaft through compact epicyclic gearing in which the torque is distributed evenly through three planet gears. It is stated that this design of transmission improves the speed of braking as the moment of inertia is considerably smaller than in conventional drives.

A cam on the crankshaft operates an ejector, and by interchanging cams the ejector stroke and time cycle can be set according to the requirements of the work. An extension of the main shaft can be used to provide an auxiliary drive for cam-controlled feeder mechanisms, &c. The main motor is electrically coupled to the oil pump motor which feeds lubricant to the main bearings, connecting-rod bearings, ram slides and other principal moving parts. In the event of a tool jamming at the bottom of the stroke the flywheel can be turned by a small gearwheel rotated by a hand shaft. Microswitches used to protect the machine in the event of tool breakage, feed defects, ejector failure, &c., are operated by safety trips. When a safety device is operated the pneumatic release is automatically tripped to brake and stop the machine within 10 deg.

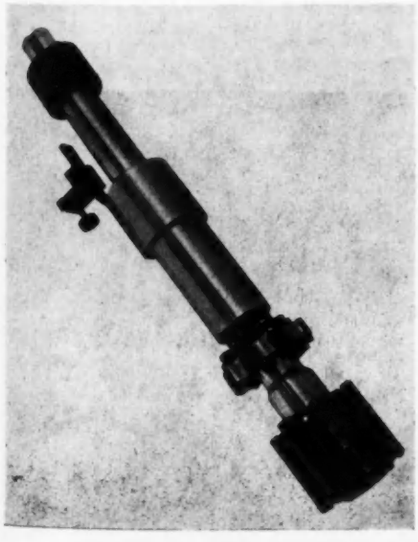
The new machine has a stroke of 4in with a maximum ram adjustment of $^{25}/_{64}$in. With the stroke and ram adjustment up, the maximum distance between the bed and the ram is 17¾in. The bed is 23in square and the ram has an area of 22in by 27in.

[Reply Card No. E1383]

Size Control Honing Tool

A HONING tool now available from Delapena and Son, Ltd., Tewkesbury Road, Cheltenham, Glos., under the trade name "Jes-Cal," incorporates a size controlling device which is arranged to stop a machine when the set bore diameter is achieved. The sizing mechanism functions independently of the machine and the hone can be used on any make of vertical or horizontal precision honing machine. The honing tools are made in a number of standard sizes to cover bores from 0·5 into 8in, and larger sizes can be supplied to order. A typical tool is shown in the accompanying illustration : it is a self-contained assembly combining a rigid driving shaft, a honing head and a size control element.

The sizing element has a tapered gauge comprising a number of tungsten carbide pads disposed around the honing head drive shaft, the gauge being free to slide on the shaft but being lightly spring-loaded towards the head. A gauge adjusting sleeve encloses the spring and is supported, together with the gauge itself, by a bearing on the hone shaft—as the sizing assembly does not rotate during the honing operation. At the upper part of the adjusting sleeve there is a trip arm and an adjustable trip block. The arm prevents rotation of the sleeve and gauge assembly, and the block operates a limit switch which allows the stones to retract when the required diameter is reached in honing.



Size control cylinder honing tool

In operation the spring loaded tapered size gauge attempts to enter the bore of the component at each downward stroke of the hone, the depth of entry progressively increasing as the bore diameter increases. On the predetermined diameter being reached the gauge enters the bore sufficiently to allow the trip block to trip the limit switch and collapse the honing stones. At this stage of gauge entry the block can be arranged to initiate any desired sequence of machine operations.

The trip block is designed to permit positive adjustment of the size gauge in increments of 0·00025in and the gauge can be quickly and easily re-set to change final honing size requirements without removing the tool from the spindle. It is stated by the makers that on multi-cylinder block honing 0·0003in limits for size and 0·0005in limits for bore roundness can be constantly maintained with the tool.

[Reply Card No. E1391]

Harmonic Analyser

A PORTABLE battery-operated harmonic analyser has been built for the British Transport Commission by the Transmission Division, Telephone Manufacturing Company, Ltd., Hollingsworth Road, Martell Road, London, S.E.21. The instrument is to British Post Office electrical design.

The analyser, which has been in use during the recent system tests on the 50 c/s electrification of the Colchester–Clacton–Walton railway line, measures the magnitude and frequency of harmonic interference from electrified traction and power distribution cables into adjacent telecommunication systems. Waveform analysis is facilitated by the measurement and display of selected harmonic amplitudes continuously and simultaneously. The instrument is fitted with

Apparatus for measuring harmonic interference in telecommunication systems. The meters show amplitudes of the fundamental and eleven harmonics

indicating meters as illustrated, but terminals are provided to enable the outputs to be fed through a translator for permanent record by an electronic digital recorder.

The analyser comprises an input attenuator panel for controlling the input voltage, an oscillator and "calibrate" panel for setting up and checking the analyser units, and twelve plug-in selective measuring units each accepting one of the following frequencies : 50, 150, 250, 350, 450, 550, 650, 750, 950, 1150, 1350 and 1550 c/s. Direct filtering is used to remove all but the particular harmonic of interest. Attenuators are included in each unit to enable voltage range switching to be used.

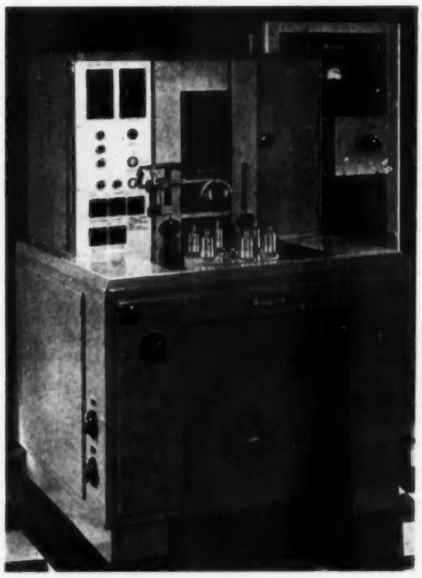
The output from each of the measuring units terminates in a 0–100mV meter. The meters provide a simultaneous display of the fundamental and the eleven harmonic voltages.

The analyser is contained in a transportable wooden case 1ft 11in by 1ft 9in by 1ft 4in. A metal framework suitable for mounting 19in panels is fitted inside the case. The twelve harmonic analyser units are mounted on the framework as a separate sub-assembly with each analyser as an individual plug-in unit.

[Reply Card No. E1392]

Universal Hardening Fixture

A UNIVERSAL hardening fixture is a recent addition to the induction heating equipment made by Delapena and Son, Ltd., Tewkesbury Road, Cheltenham, Glos. Four interchangeable alternative work handling attachments are available with this equipment, which is illustrated coupled to one of the firm's E 9/12 induction heaters, and fitted with a six-station indexing table. With this table the machine can be used on an automatic transfer line or as a semi-automatic fixture with manual loading and unloading. The operating cycle can be arranged to provide a repetitive sequence of indexing, positioning of the work coil, heating, quenching and withdrawal of the coil ; the heating and quenching periods being independently adjustable. During heating and quenching the work-piece can be allowed to remain stationary or to be rotated on its own axis, and the coil and quench can be traversed axially if required.



Universal hardening fixture with induction heater

A two-position shuttle jig which can be fitted on the machine can be provided with work holding adaptors and used for hardening, brazing or heat-treatment of components. With this jig heating can take place at one station whilst the other is being unloaded and reloaded. A rotating change-over jig with two stations can be used in cases where rotation of the work-piece is required during heating. Each work-piece holder has a friction drive wheel which engages a driving shaft below the jig plate at the heating station.

A shaft hardening attachment provides for heating by axial traverse of components up to 15¾in long and 9·45in diameter, with or without rotation. The maximum travel of the work coil for this attachment is 11·8in and within this distance heating can be constant during traverse or in selected localised zones. Spray quenching follows heating and provision is made for initial preheating dwell at the commencement of each operation. Once the initial settings have been made the complete sequence—of fast traverse, dwell, heating and quenching traverse, return to loading position and stopping—is initiated and performed on depression of a single button.

SHORTER REPORTS *(Continued)*

High-Pressure Solenoid Valve

A SOLENOID valve for a working pressure up to 4500 lb per square inch adaptable for the remote operation of pneumatic actuators and similar duties, made by the Hymatic Engineering Company, Ltd., Redditch, is stated to have extremely low leakage and effect venting of the downstream system when it is closed. This valve, illustrated herewith, has a servo action and its through area size is $\frac{3}{8}$in B.S.P.

Solenoid valve for pressure up to 4500 lb per square inch. This valve has a very low leakage which allows venting of the downstream system when the valve is closed

The solenoid in the valve assembly operates two ganged pilot valves which admit high pressure to (or exhaust to atmosphere from) a chamber between two separate pistons. One of these pistons forms the main inlet valve and the other operates through a pin and ball type breather valve for the downstream side. Balanced springs in the solenoid assembly prevent inadvertent operation of the valve by sudden accelerations and limit the loading applied by the solenoid on the lower valve seat.

When the solenoid is unenergised high-pressure gas is admitted through one of the pilot valves to the chamber between the two pistons. This pressure assists a spring in holding the main valve piston on its seat and simultaneously moves the breather piston, thereby opening the ball breather valve, which vents the downstream system to atmosphere.

When the coil is energised the pilot valves are moved, cutting off the gas supply to the chamber between the pistons and venting the gas in it. The high-pressure gas then acting on the effective annular area of the main valve opens it and allows a free flow of gas. The breather valve is closed by action of its spring and prevents leakage from the downstream system. Subsequent de-energising of the solenoid allows gas to be admitted to the central chamber and the inlet valve, assisted by a spring, closes ; the breather piston moves and the pin lifts the ball off its seat and vents the downstream system.

One model of the new valve has a high-speed response time of less than thirty-five milliseconds, whilst in standard form it has a response time of 150 to 300 milliseconds. It can be operated over a temperature range of -45 deg. to $+70$ deg. Cent. and will work unrestrictedly over the full range of accelerations of $\pm 12g$.

[Reply Card No. E1401]

In Situ Construction of Concrete Floor and Roof Slabs

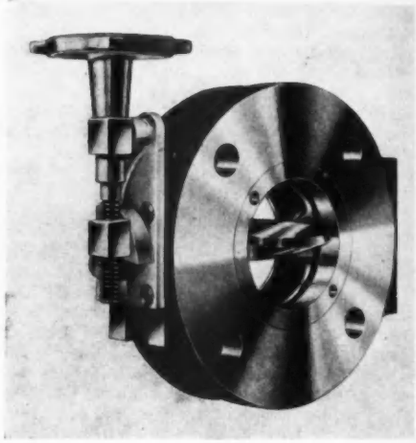
MANY new systems for the construction of floor and roof slabs in reinforced or prestressed concrete have been introduced in recent years. The one which is before us now is of interest because it relies entirely on *in situ* construction for the reinforced concrete work, but simplifies the formwork required by utilising panels of wood-wool, which are incorporated in the permanent work in which they serve several purposes.

The two illustrations show the system well. It is called the " Neolith " system and was designed by Concrete Structures, Ltd., of Halifax, and is being manufactured by Neolith, Ltd., of Newcastle. The basic elements of the system comprise five standard wood-wool components, all made in 6ft lengths. The components are supported on steel centering or timber battens, and can be formed into hollow box shapes, solid make-up pieces, &c., as dictated by the general design of the reinforced concrete slab. As can be seen in the diagram, a standard arrangement conveniently forms the moulds for a series of " T "-beams, reinforcement being placed on clips and spacers. Services can be incorporated within the depth of the floor, (with some limitation on the provision of transverse service ducts) and the wood-wool soffit forms a convenient base for plastering. Spans up to 20ft or 30ft, depending on the loading, are catered for by the standard components of the system, but clearly " boxes " of any size can be easily made, and there is a standard soffit component which can be used as the basis of designs for long spans or special conditions. Generally the wood-wool components have a thickness of about 1in ; they can be sawn on site and they are light in weight, having good thermal and acoustic properties, and a class " A " fire rating. The heaviest of the standard components weighs 80 lb.

[Reply Card No. E1402]

Pivoted Disc Valves

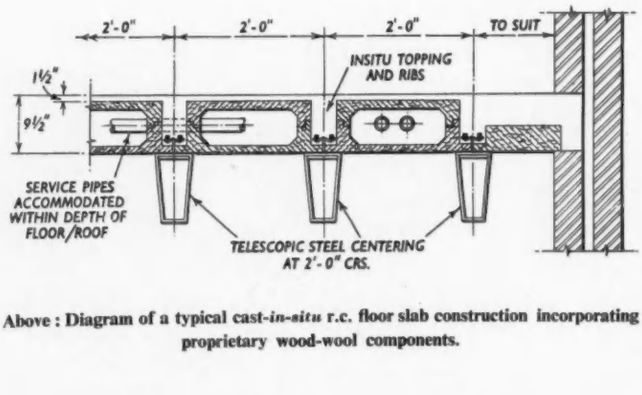
WE illustrate a pivoted disc valve to be produced under licence by Charles Winn and Co., Ltd., Birmingham, and marketed as the " Winn-Flexiseat " by the B.W. Valve Company, Ltd., 140, Granville Street, Birmingham. In this butterfly design valve a separate ring of flexible material moulded round a metallic core is located in a deep annular groove in the body, where it is held by a screwed, adjustable retaining ring. This ring imparts the necessary compression on the flexible ring to position the seating surface accurately and control it in relation to the disc.



Pivoted disc valve with inset flexible sealing ring

It is stated that the initial range of these valves in the 150 lb per square inch class for water, gas, air and oil will shortly be available in 3in to 6in sizes, followed later with sizes up to 12in and eventually 24in.

[Reply Card No. E1403]



Above : Diagram of a typical cast-*in-situ* r.c. floor slab construction incorporating proprietary wood-wool components.

Right : Placing the wood-wool components and the reinforcement

Electro-Pneumatic Valve Positioner

A POSITIONER developed by British Arca Regulators, Ltd., Sisson Road, Gloucester, is designed to allow the use of pneumatic control valves in conjunction with electrical controllers. This equipment, to be seen in a valve installation in the accompanying illustration, provides a linear relationship between the operating current and the valve stem position regardless of the unbalance forces on the valve, if required, non-linear characteristics can be obtained.

Electro-pneumatic valve positioner providing a linear relationship between operating current and valve stem position regardless of valve unbalance forces

The positioner incorporates an electro-magnet system in which the operating current and valve position are compared and a pneumatic pilot valve system which is operated by the electro-magnetic system to move the valve so as to maintain the required current/valve characteristic. The actual diaphragm pressure does not enter into the current/valve position relationship at all, the necessary air being admitted or released as required to maintain balance in the electro-magnetic component by moving the valve stem to the position required by the operating current. There is no intermediate conversion of current to air pressure.

It is stated that the fundamentally new principles of valve position feedback embodied result in total elimination of back lash and a high order of repeatability. Valve position is made to directly vary the reluctance of the electro-magnetic circuit in a direction inverse to the change of current. In this way the valve is moved so as always to maintain the force produced in the electro-magnetic component constant. The full working force is therefore available for all operating currents and sensitivity is substantially constant throughout the range when expressed as a percentage of the working current.

Means of adjustment are provided on the positioner so that the full range of operating current can be made to give less than the full available travel of the valve. This, combined with a zero adjustment, enables a reduced working travel to be located as required in the available valve stroke.

Full valve air power is available for a deviation of 1 per cent (in either current or valve position) between operating current and corresponding valve position. The dead zone is stated to be of the order of $\pm 0{\cdot}25$ per cent. The three standard operating current ranges and corresponding coil resistances available are: 5mA d.c. (resistance 3500 ohm); 10mA d.c. (resistance 1700 ohm); and 15mA d.c. (resistance 1200 ohm). The positioners have an approximate air consumption 0·2 c.f.m.

[Reply Card No. E1411]

Automatic Paint Spraying Machine

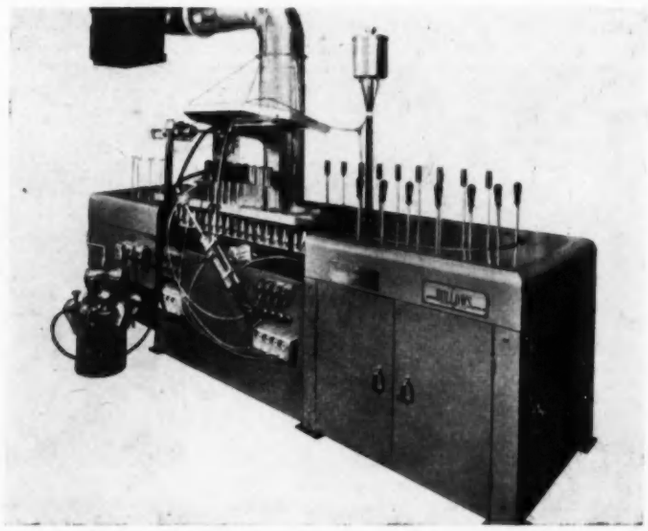
AN automatic paint spraying installation which is now made by Alfred Bullows and Sons, Ltd., Long Street, Walsall, Staffs, is illustrated below. It incorporates a cabinet base with a conveyor track for the fixtures of the components to be painted, a spraying station, a spray gun carried on a traversing unit and a down-draught exhaust system. An electric motor enclosed in the base drives a gearbox via a five-speed step cone pulley which, through a series of shafts and cams, drives the conveyor chain, operates the spray gun traverse motion and the automatic operating valve of the spray gun. The length of the spray gun traverse is determined by interchangeable cams and the period of spraying by adjustable cams.

Dependent upon the rate of production required and the type of article to be sprayed, the set can be fitted with a 2in, 3in, 4in or 6in pitch chain into which workholders fit. A standard 25ft of chain is supplied but this length can be increased in an initial installation or extended at a later date if required. Workholders of various sizes and shapes are available. The conveyor is in constant motion and the gun, when spraying, follows the work. An automatic spray gun is rigidly mounted on an hydraulically operated cylinder arm and when changing to articles of varying sizes, adjustment is quickly and easily effected by changing cams or adjusting cam settings to cover the gun motion and the spraying time. To enable accurate changes to predetermined spraying angles the gun arms and mountings are calibrated.

The down draught exhaust system is ducted vertically through the centre of the machine, opposite the spraying station. Paint-laden air is carried down to an easily removed castor-mounted separator, which incorporates an effective system of circular baffles, and the exhaust air is then taken up and out to atmosphere.

Extra gun motions can be fitted, if specified, with an additional spraying station, and if required a water wash exhaust system can be provided. A mechanical memory device available as an optional extra automatically signals the machine when workholders are loaded or not and in addition to saving paint prevents unloaded workholders from being painted. A machine can be supplied with either 25ft of chain or a floor mounted conveyor for transportation to an unloading station, where air drying materials are used, or to a stoving oven. Steplessly variable speed drives can also be built into a standard unit.

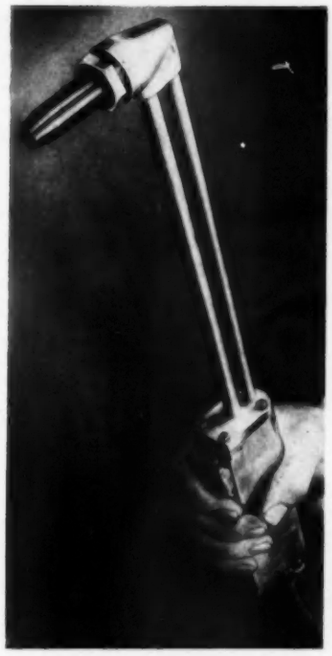
[Reply Card No. E1412]



Automatic paint spraying machine

Powder Welding Torch for Hardfacing

A DEVELOPMENT of Deloro Stellite, Ltd., Shirley, Solihull, Warwickshire, in collaboration with F. W. Berk and Co., Ltd., is a powder welding torch for hardfacing components with "Stellite." This torch, to be seen in the illustration below, consists essentially of an adaptor on a "Schori" powder spraying pistol. It uses standard "Stellite" powders and argon as the conveying gas.



Powder welding torch for applying "Stellite" hardfacing materials

It is stated that this system of powder welding for hardfacing is particularly suitable for thin overlays of $^1/_{32}$in to $\frac{1}{8}$in with a preferred maximum of $\frac{1}{4}$in in a band up to 2in wide. The best results are obtained on base metals from $\frac{1}{4}$in to $\frac{3}{4}$in thick although weldable material thicker than $\frac{3}{4}$in can be handled. The process is claimed to be considerably faster than hardfacing using arc or gas equipment whilst giving a smooth deposit with low dilution from the base metal.

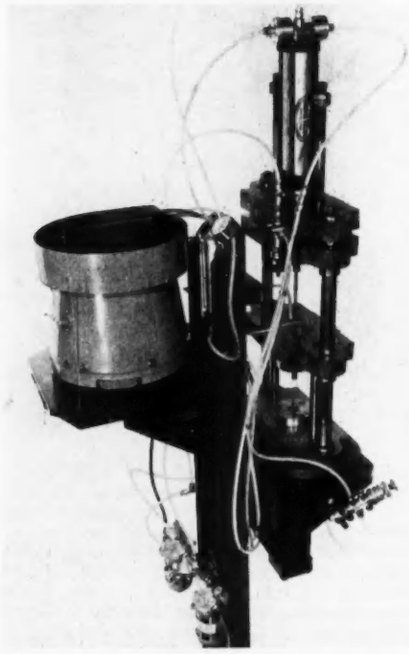
[Reply Card No. E1413]

SHORTER REPORTS *(continued)*

Dowel Inserting Press

AN air-operated press has been developed by Rhoden Partners, Ltd., 19, Fitzroy Square, London, W.1, for simultaneously feeding and inserting two dowel pins in component assembly. It is intended for repetition work and can be tooled to cover a number of different types of dowel pins in any number required. The general design of the machine can be seen in our illustration.

The bottom bolster of the press is connected by pillars to the top crosshead, on which is mounted a compressed-air-operated impact cylinder having its piston-rod anchored to a sliding bolster. Mounted on the underside of this sliding bolster are the dowel inserting punches in a punch plate with a backing strip, as in conventional press-tool practice. Beneath the upper sliding bolster is a second sliding bolster which acts as a work clamp and guide for the punches. This sliding bolster is connected



Compressed-air-operated press for automatically feeding and inserting dowel pins in component assemblies

to the tops of two inner rods, which are connected at their lower ends by a plate on which is mounted an air cylinder. The rod of this cylinder is screwed into the underside of the machine platform on which the whole of the press assembly rests. The two inner rods are free to slide through holes in the stationary bottom bolster and through clearance holes in the machine table so that when the lower double-acting air cylinder operates it moves the work clamping bolster up and down. Mounted on the underside of the clamping bolster is a tooling block shaped to hold the component. A tooling plate, for locating the component, is mounted on the stationary bottom bolster. If the dowel holes go right through the components being assembled it is convenient to use these holes to locate on to spring-loaded pilot pins so that they sink out of the way as the dowel pins penetrate the holes.

A "Syntron" vibratory bowl feeder at the side of the press is loaded with dowel pins in bulk, and sorts, orientates, and delivers them to the outlet in two single lines; from this outlet two short flexible tubes lead to a breech mechanism. This breech mechanism accepts the single lines of dowel pins and during the sequence of the machine transfers one from each tube to two flexible outlet tubes whence they are discharged by compressed air to the holes of the work clamp tool.

In the working cycle the operator places the component, or number of components if several parts are to be dowelled together, on to the pilot pins projecting up from the lower fixed bolster. Upon two push buttons, one at each side of the machine platform, being depressed to initiate the automatic cycle, air is admitted to the lower double-acting air cylinder, which moves the lower sliding bolster downwards to clamp the components. At the bottom of the stroke, a pneumatic valve is operated to energise the air cylinder mounted on the breech mechanism, which causes a shuttle inside the mechanism to isolate two dowel pins from the supply and to place them into a position whence they are discharged through their individual tubes and come to rest supported on the tops of the pilot pins projecting through the workpieces. Air is then admitted to the impact cylinder on the crosshead to drive the upper sliding bolster with its punches down and punch the dowel pins into their holes.

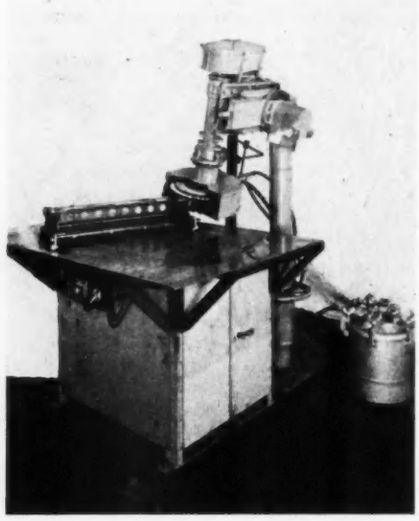
After its downward stroke the impact cylinder returns to its "up" position and at the same time the double-acting air cylinder reverses to raise the punches and the work clamp clear of the component. This automatic cycle, it is stated, occupies about 2½ seconds.

[Reply Card No. E1421]

Polishing Machine

AN automatic polishing machine for profiled components has been designed by B. O. Morris, Ltd., Briton Road, Coventry, for batch production polishing where the installation of a large fully automatic machine would not be an economical proposition. The machine is provided with a 40in by 30in worktable, as shown in the photograph we reproduce, or a 60in by 40in table for larger work. The work is held by quick-operation clamps in a special jig suited to its shape and a drive in the table moves the jig around at a pre-set speed to pass the work below the polishing head.

Each jig has a box base shaped to the required profile and a roller chain fastened around the lower sides of the base forms a rack. Pads built into the underside of the jig base provide low-frictional supports for the jig on the table to minimise the effort required for free movement during the polishing operation. Projecting up from the table surface to the level of the jig chain rack is a driven sprocket wheel and an adjacent freely-rotating pressure wheel, which



Automatic polishing machine for profiled components

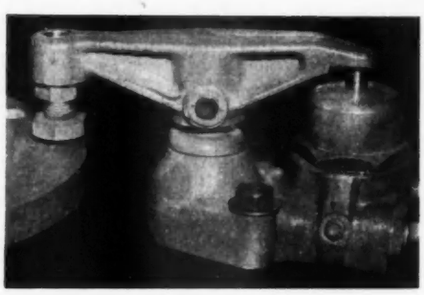
contacts the inner wall of the jig and holds the rack in constant mesh with the sprocket. The sprocket is driven by an electric motor through a variable speed gear. With this drive the jig is moved on the table over a contour predetermined by its base profile to carry work of corresponding shape past the polishing mop.

A pneumatic control is provided for the pressure roll, which can be retracted below the level of the table by movement of a lever at the front of the table. The polishing heads, with 16in diameter by 5in wide or 12in diameter by 3½in wide mops, available for use with the machine are supplied as complete units with their drives. They have means of universal adjustment to set the angle of the mop in accordance with the requirements of the workpiece. Liquid polishing compound is applied, in the form of a spray, to the mop by an air system with cam-adjusted timing for automatic application or under control of a foot-operated valve by the operator. For handling large components extension sections can be fixed on the table and, if required, two machines can be coupled together for two-pass polishing of work pieces.

[Reply Card No. E1422]

Hydraulic Clamp

A HYDRAULICALLY-OPERATED clamp which has been developed by Power Jacks, Ltd., Agnes Road, Acton, W.3, has a pivoted arm which automatically swings clear of the workpiece to facilitate positioning and unloading. The clamp, to be seen in the illustration, has a heavy base through which it is bolted to a machine table, and at the rear is provided with a ¼in B.S. inlet port connection for the hydraulic supply. The arm is pivoted on a column which is rotated through 90 deg. in respect to the base and into the clamping position by hydraulic fluid being admitted to a cylinder having a spring loaded piston. When the clamping position has been reached the rear end of the arm registers over a hydraulic ram at the rear of the base. Fluid is then automatically admitted to the ram

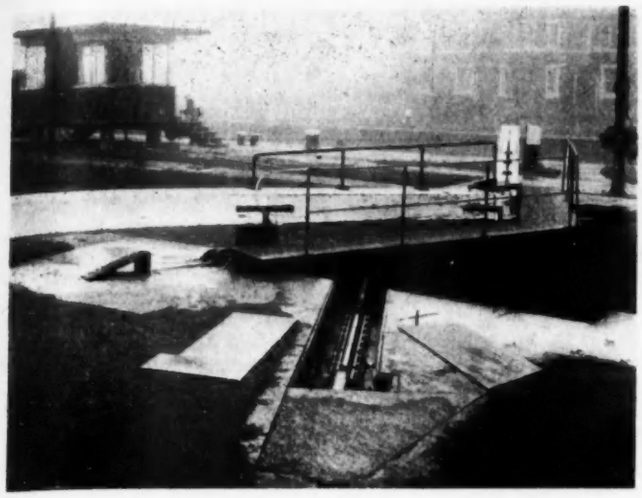


Hydraulic swing clamp in operation

chamber and the ram rises to tilt the arm on the column and apply the clamping force through its domed pad. When the pressure of hydraulic fluid is released at the end of the machining operation the clamping arm is retracted and then the spring pushes the piston back to turn the column and carry the arm clear of the work.

The clamp, which requires 0·217 cubic inch of pressure fluid for its operation, has an effective locking stroke of 0·25in and, with the pad adjustment provided, work from 1·5in to 2in thick can be held when the clamp is mounted on the same surface level as the component. With a normal hydraulic operating supply of 2000 lb per square inch a clamping force of 900 lb is exerted at the pad; at the maximum operating pressure of 2500 lb the clamping force is 1160 lb. When in the clamping position the pressure pad centre is 1·56in from the front extremity of the base.

[Reply Card No. E1423]



Hydraulic ram operated lock gates with control cabin in the left background

Lock Gate Power Operating Equipment

HYDRAULIC equipment for operating lock gates is now made by Dowty Hydraulic Units Ltd., Ashchurch, Glos., and the company recently issued particulars of an installation at Diglis Lock, Worcester. There are two locks at Diglis, a large one measuring 142ft by 30ft and a smaller one of 94ft by 20ft. Each lock has two 30ft high gates of greenheart, the outer gates of the large lock each weighing 14 tons and the inner gates about 12 tons.

The large lock is at present being equipped with hydraulic operating mechanism for the gates whilst the conversion to power operation of the gates of the smaller lock, to be seen in our illustration, has been completed. The installation includes a power pack and control valves housed in a new cabin on an island between the two locks. In this power pack an industrial gear pump immersed in a 12 gallon tank of hydraulic fluid is driven at 1500 r.p.m. by a 7½ h.p. electric motor and delivers 6 g.p.m. at 1500 lb per square inch to the system through a relief valve. Pressure fluid is delivered to open-centre control valves whence it is directed to either end of an hydraulic jack connected to each lock gate. Built-in safety measures to protect the equipment include shear pins at the connection of the jack rods to the gates, a cross-head sliding arrangement for supporting and guiding the jack rods, and a restrictor-relief valve mechanism giving metering characteristics in the event of the gates tending to stick or being butted by a craft in the lock.

When a craft has entered the lock the two open gates are closed within a minute after the power pack motor has been switched on and the relevant control valves operated. Water is then admitted, or released, from the lock by 6ft by 4ft sluice gates operated by screwed shafts driven by an electric motor. Whilst the water level is changing the lock-keeper walks to the opposite end of the cabin ready to operate two levers controlling movement of the outlet gates.

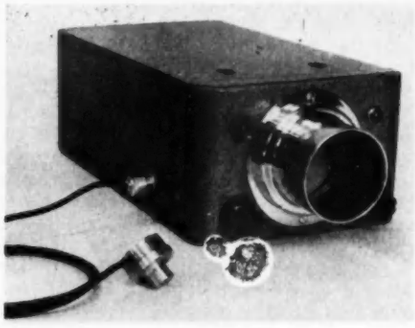
[Reply Card No. E1431]

Grinding Indicator

IT is announced by B. O. Morris, Ltd., Briton Road, Coventry, that an electronic grinding indicator the firm has been making for Rolls-Royce factories for several years is now being made available to industry in general. This instrument is designed to show visually when a grinding wheel is in contact with the workpiece on a machine—which is particularly advantageous when the wheel itself is obscured by coolant or inside a workpiece being ground internally. In other applications also, such as when remote indication of contact is required, no spark is produced on contact or in high precision grinding, the instrument can be used to good advantage.

The indicator, illustrated here, consists of two main assemblies—a pick-up head connected to a cathode tube indicator. The pick-up head is positioned near the grinding wheel using a magnet mounting or a threaded stub. Vibrations from the grinding wheel are picked up by this unit and are transmitted to the indicator where they are shown in the form of a "V" on the cathode-ray tube. These "V's" take various forms in accordance with the work to wheel contact and show if grinding is consistent, irregular due to eccentricity, or too heavy.

The instrument is designed to accept the high frequency vibrations resulting from the high peripheral speeds and small particle size of the



Electronic grinding indicator detecting wheel contact on work

wheel and reject the lower frequency vibrations caused by bearing rotation and other machine movements. A control can also be used to eliminate the effect of spurious high frequency vibrations. It is stated by the makers that the equipment has been used to indicate a 25 micro-inch cut and it is considered that this is by no means its limit.

[Reply Card No. E1432]

Continuous Weighfeeder for Process Materials

A CONTINUOUS weighfeeder has been developed by Baker Perkins, Ltd., Peterborough, to meet the basic material feeding and weighing requirements of continuous processing installations in industry. The basic machine is made in several versions to cover widely differing applications in the process industries and is designed to meet all weighing and feeding requirements up to the stage of specific installation. It incorporates a system of continuous weighing which gives early indication of changes in weight and incorporates means of speedy and accurate correction, whilst its mechanism is fully protected against the ingress and collection of dust which could lead to possible errors in weighing.

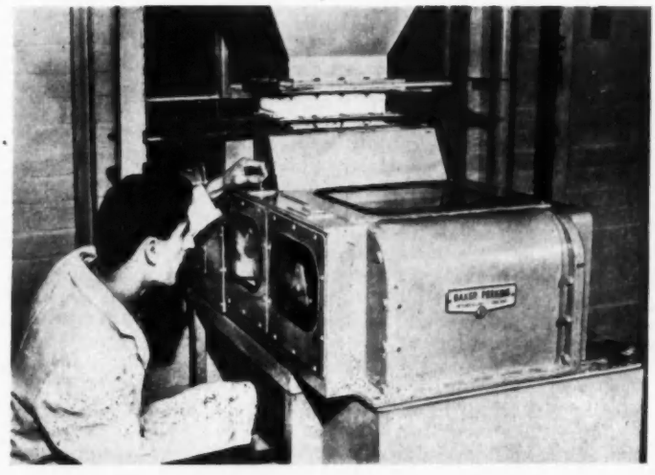
The weighfeeders are available to cover outputs from 50 lb to 5 tons an hour and individual machines can have an output range of about 10 to 1 within their capacity limits. The accuracy in operation is stated to be plus or minus 1 per cent, based on one minute readings, over any part of a machine's range. A typical machine of the new design is illustrated below.

Each machine incorporates a materials hopper with a gate outlet in the base delivering on to a fixed length of conveyor beneath which there is a weight sensing mechanism. In the double outlet gate an outer gate operates over an inner gate with a central slot machined in it. When large corrections in material flow are required these two gates are operated in unison, whilst for normal working the outer gate only is operated to expose more, or less, of the central slot for the passage of material. The signal for operating the outlet gates is initiated by the weight detection device which consists of a weigh deck or flat plate platform below the conveyor. The weigh deck is arranged as a lever with its point of maximum leverage situated only 3in from the hopper outlet gates. The mechanism is designed to weigh continuously the material flowing on to the conveyor.

The weigh deck, situated beneath and completely covered by the conveyor belt, is fully protected against the ingress of dust and is rigidly fixed to a bar at the pivot end of the conveyor belt. Rubber diaphragms seal the ends of this bar as they pass through the two main side frames of the machine to isolate the dusty working chamber. One end of the bar is extended into a sealed box where it is connected to a steelyard mechanism on which the desired output is set and from which deviations in delivery are signalled.

An auxiliary belt drive used is designed to give a non-slip transmission and provide a large area of contact with the conveyor belt, whereby there are avoided the possible fluctuations in conveyor tensions, which could register as weight change at the point where the conveyor passes over the weighing head. The highly tensioned auxiliary belt runs under the conveyor belt at the hopper feed end and both belts are supported on a fixed deck. Through this deck the load of material bearing down on the conveyor serves to press it into harder contact with the driving belt to overcome the effects of any drag from the deck.

[Reply Card No. E1433]



Continuous weighfeeder for process plant

INDUSTRIAL NEWS

Miners' Wages

Following resumed discussions in London last week between the National Coal Board and the National Executive of the National Union of Mineworkers on the Union's claim for an increase in wages for day-wage men of 18s. a week and for craftsment of 30s. a week, the National Executive Committee of the Union has agreed to recommend to its Areas acceptance of the Board's offer of an increase of 8s. 6d. a week for day-wage men with increases of between 11s. and 15s. a week for craftsmen and 11s. a week for winding engine-men. In a jointly agreed statement issued after the discussions it was announced that, in addition, highly-skilled craftsmen with special statutory duties are to have their shift allowance increased by 1s. The increases are to take effect from the pay week which includes January 2, 1961, and are expected to add some £7,500,000 a year to the industry's wage bill.

The National Coal Board and the National Union of Mineworkers are expected to meet shortly to discuss methods of increasing productivity and efficiency in the pits.

Shipbuilding Statistics

According to returns made by The Shipbuilding Conference, seventy-two merchant ships of 210,000 tons gross were ordered from British shipbuilders during the last quarter of 1960, to bring the total orders for the year up to 248 ships of 627,000 tons. This latter figure compares with 198 ships of 319,000 tons ordered in 1959 and 144 ships of 497,000 tons in 1958. Cancellations for the year totalled twenty ships of 165,000 tons. At the end of December, 1960, the order book stood at 440 ships of 3,348,000 tons gross representing a value of £500 million, including fifty-two ships of 562,000 tons valued at £75,000,000 to foreign account. The current total of orders represents a reduction of 3,480,000 tons from the 1957 total of 6,828,000 tons and during this period more than 4,000,000 tons were completed, 850,000 tons were cancelled and orders were received for 1,400,000 tons. Keel laying, which is an indication of future output, has been greatly reduced: in 1960 less than 1,000,000 tons were laid down, a figure which is 150,000 tons lower than in 1959, about 300,000 tons less than in 1958, and more than 500,000 tons below the 1957 total.

Co-operation in Electrical Exports

The British Electrical and Allied Manufacturers' Association announces that at a meeting held in London last week more than 130 export managers and senior executives of the electrical industry welcomed the suggestion that the Association should make immediate arrangements to put firms in touch with makers of complementary equipment with a view to joint sales efforts, joint market research and collective exhibitions overseas.

A confidential questionnaire will be completed by each of the firms represented, enabling the Association to bring together those firms wishing to co-operate in export promotion. In replying to the questionnaire firms will give details of the products they wish to export, the overseas territories in which they would like to co-operate, any existing overseas facilities they would be prepared to share and whether they would like to co-operate with firms in other industries.

Attention was drawn at the meeting to the many advantages of pooling resources in the most competitive markets, bearing in mind the high cost of maintaining fully trained and experienced sales engineers abroad. It was also suggested that small teams representing groups of manufacturers might be sent to overseas territories. Several of the largest firms in the electrical industry offered to provide help to smaller firms manufacturing complementary products, by sharing their overseas facilities.

Electrical and allied products represent about one-tenth of all British exports of manufactured goods.

Manufacturing Activity in Australia

A survey of manufacturing activity in Australia's basic materials and engineering industries, prepared in 1960 by the Commonwealth Department of Trade, has been published this week. It is based on interviews with 800 firms in thirty-six different industries, most of the interviews being carried out in May, 1960. The groups covered included building and construction materials, ferrous and non-ferrous metals and metal processes, chemicals, textiles and paper, and engineering products including heavy equipment, electrical engineering and other engineering products. It has been estimated that the rate of output of each of the main sectors of industry covered was some 10 per cent higher at the time of the survey than it had been a year earlier. In the same period employment increased by just over 6 per cent.

In the engineering products group some concern has been expressed about the possibility of increased import competition, the survey says, but with orders on hand at high levels, manufacturers generally expect production and sales to continue their upward trend. The industries surveyed generally were working at about 80 per cent or more of productive capacity. Employment in the industries covered by the survey was about 7 per cent higher in March, 1960, than in March, 1959, although most firms reported that they were finding it difficult to secure skilled tradesmen. Exports of the engineering products groups of industries amounted to more than £6,000,000 in 1958/59.

Exports Credits Guarantee Department

The Export Credits Guarantee Department has announced that during 1960 it insured more export business than ever before under its "commercial" insurance scheme, a total of £694,500,000. The figure for 1960 showed an increase of 8·8 per cent over the previous year's total of £638,200,000, the Department says, although the shipments declared for export in the last quarter of the year had been valued at £5,000,000 less than in the corresponding period of 1959.

In the field of large capital goods, the Department states, the new business insured during the year amounted to £103,200,000, compared with £86,700,000 in the previous year. This new business in the last quarter of 1960, totalling £26,000,000, included electrical equipment valued at £7,300,000, textile plant and machinery £4,100,000, sugar refinery plant £7,100,000, fishery vessels £2,000,000, and aircraft £2,300,000.

At the end of the last quarter of 1960, the number of short-term policies current was 5232, compared with 5112 at the beginning of the quarter, and 4852 at the end of the corresponding quarter of 1959. New medium-term business to the face value of £26,000,000 was transacted during the quarter, compared with £17,700,000 in the previous quarter and £10,600,000 in the corresponding quarter of 1959. The gross value of all short-term and medium-term insured business, including external trade, declared as shipped during the quarter amounted to £173,800,000, the Department says, compared with £180,200,000 in the previous quarter and £178,800,000 in the corresponding quarter of 1959.

Tally Clerks' Strike

"The ripple of damage" caused by the tally clerks' strike at the London Docks spread in ever-widening circles and affected the country's economy at many different points, the London Chamber of Commerce says in its interim report on the effects of the stoppage. The strike was unofficial and ran from September 20 until October 17 (THE ENGINEER, December 2, 1960). All members of the London Chamber were asked by letter to provide information on their experiences as a result of the strike, and replies were received from over 1000 firms. The London Chamber believes that the presentation of this information might help to convince the nation at large that a situation exists which can no longer be tolerated if our oversea trade is to prosper.

To read through the replies, the report says, is to receive a vivid impression of the immediate cost to the nation, the range of the damage, the frustration and loss of goodwill resulting and the long term dangers of the Port of London's lowered reputation. The object of this interim report, the London Chamber says, is to convey that impression as far as possible by a number of sample extracts and to present a strictly factual account of the consequences of the strike.

Even though the financial loss is serious—the report gives some figures which, it says, might suggest the scale of the loss—it is in the long term less serious than the damage done to Britain's reputation in oversea markets.

No attempt has been made in this interim report to apportion blame or to analyse the causes of the strike. The London Chamber of Commerce is, however, preparing a further, final, report, which will deal with the wider question of port working and will consider some of the suggestions put forward by members for improving the position.

PERSONAL AND BUSINESS

Appointments

MR. H. B. MORRIS has been appointed to the board of directors of Wickman, Ltd.

MR. N. BARDSLEY, M.I.Mech.E., has been appointed chief engineer of Plowright Brothers, Ltd.

MR. S. A. CLODD, M.I.Prod.E., has been appointed to the board of directors of E. K. Cole, Ltd.

MR. N. R. R. BROOKE has been appointed a director of Guest, Keen and Nettlefolds, Ltd.

DR. A. E. W. AUSTEN, A.M.I.E.E., has been appointed an executive director of C.A.V., Ltd.

MR. PETER E. M. SHARP, A.M.I.E.E., general manager of Westrex Company, Ltd., has been appointed a director.

MONSANTO CHEMICALS, Ltd., announces that a new position, senior scientist, has been created for Dr. I. S. Wilson, a member of its technical staff.

MR. F. D. LOWEN has been appointed manager of the light power motor factory at Thorne, near Doncaster, of Associated Electrical Industries, Ltd.

MARTONAIR, Ltd., has appointed Mr. M. R. Taylor as technical representative for East Staffordshire, Derby, Sutton Coldfield and northern Birmingham.

MR. MORLEY A. GRIFFITH-JONES has been appointed general sales manager of Chloride Batteries, Ltd., Exide Works, Clifton Junction, Swinton, Manchester.

MR. JOHN PORTER has been appointed purchasing manager at the Ebbw Vale Works of Richard Thomas and Baldwins, Ltd., in succession to the late Mr. R. B. Fisher.

MR. W. L. WATSON, works manager at the Northampton Works of Pollard Bearings, Ltd., has now moved to the principal works at Ferrybridge as works manager.

MR. P. G. HODGKINSON, A.M.I.Mech.E., has been appointed to take charge of the production and operational research section of the British Shipbuilding Research Association.

MR. S. TUDOR has been appointed production manager of Alfred Ellison, Ltd., and has been succeeded as representative in the north of England by Mr. J. K. Gascoigne.

CHASESIDE ENGINEERING COMPANY, Ltd., announces the appointment of the following additional directors : Mr. Douglas A. Findlay, Mr. John E. T. Watson, and Mr. Derek R. Webster.

MR. J. F. DOUGLAS, A.M.I.C.E., has been appointed head of the department of mechanical engineering at the Borough Polytechnic, London, S.E.1, in succession to Mr. G. L. H. Bird.

Dowty Rotol, Ltd., announces that Mr. D. G. S. Barrett, A.R.Ae.S., has been appointed service manager in succession to Mr. W. Spires who was recently appointed to the company's board.

SMART AND BROWN (MACHINE TOOLS), Ltd., has appointed Mr. D. H. Bing as sales engineer in succession to Mr. I. T. Jackman. He will operate from the sales office, 25, Manchester Square, W.1.

MR. D. D. TEASDALE, secretary and chief accountant of Fawcett Preston and Co., a member of the Metal Industries Group, has been appointed general manager of the company and has joined the board.

MR. C. SMITH has been appointed assistant general manager of the ore mining branch of the United Steel Companies, Ltd., and has been succeeded as group manager, underground mines, by Mr. F. Harrison.

THE MINISTRY OF AVIATION has announced that Mr. Kenneth H. Staple has been appointed as a member of the board of British Overseas Airways Corporation for a period of three years from January 18, 1961.

RUSTON-BUCYRUS, Ltd., has announced that Mr. G. E. Savory has been appointed assistant managing director. Mr. F. Wildmore has been appointed to the board of the company as director and commercial manager.

MR. D. K. FRASER, joint managing director of G. A. Harvey and Co. (London), Ltd., has been appointed managing director. Mr. H. E. Cooper has relinquished his office of joint managing director but remains a director.

MR. R. C. BILBOROUGH has been appointed sales manager to the Catchpole Engineering Company, Ltd. Mr. G. Wood has been appointed sales office manager and Mr. L. G. Peveritt has been appointed chief technical service engineer.

THE MINISTRY OF POWER announces that Mr. M. A. L. Banks, F.R.I.C., M.I.Chem.E., a managing director of the British Petroleum Company, Ltd., has been appointed a member of the Advisory Council on Research and Development.

E. K. COLE, Ltd., states that following the Ekco-Pye merger, Mr. N. A. Twemlow, director of Pye, Ltd., has been appointed to the board of E. K. Cole, Ltd., and Mr. W. M. York, commercial director of E. K. Cole, Ltd., becomes a director of Pye, Ltd.

THE HYMATIC ENGINEERING COMPANY, Ltd., has announced three new appointments in its Hydrovane division. Mr. D. Fereday has been appointed sales manager ; Mr. G. Seaton has been appointed home sales supervisor, and Mr. J. Cahill has been appointed sales representative for northern England. He will be based at Bradford.

GOODYEAR TYRE AND RUBBER COMPANY (GT. BRITAIN), Ltd., states that Mr. R. J. M. Perrett, has been appointed district manager, Bristol, Western division, and has been succeeded as district manager, Birmingham, Midland division by Mr. D. F. Towers, previously district manager, Nottingham. Mr. P. G. L. Drabble has been appointed district manager, Nottingham, Midland division.

THE MINISTRY OF AVIATION has announced the appointment of the chairman and members of the Scottish Advisory Committee for Civil Aviation. The membership is as follows : Mr. J. N. Toothill, chairman ; Mr. W. P. Broomfield, Mr. Alfred Carruthers, Mrs. Edward Denny, Mr. J. G. Dunbar, Mr. Londsay D. Gumley, Mr. Iain Hilleary, Mr. J. Gibson Kerr, Mr. J. C. Lang, Lord Macdonald, Dr. J. W. Macfarlane, M.I.E.E., M.I.Mech.E., Mr. Maurice McManus, Mr. G. Middleton, Brigadier Sir Keith Murray, Mr. Donald J. Stewart, and Mr. Robert Taylor.

BRIGHTSIDE ENGINEERING HOLDINGS, Ltd., announces the following appointments : Graham Firth Steel Products, Ltd., Mr. L. Graham Firth has been elected chairman in succession to Mr. E. H. King who retains his seat on the board ; Mr. A. R. Lancashire has been appointed assistant managing director ; Mr. Tom C. Firth and Mr. R. Ivor Slater have been elected directors, and Mr. N. G. Welch and Mr. B. J. Byrne have relinquished their seats on the board ; Mr. H. J. Nash has succeeded Mr. B. J. Byrne as secretary. Metal Mouldings, Ltd., Mr. L. Graham Firth has been elected chairman in succession to Mr. N. G. Welch who has resigned from the board. Mr. Ivor Slater has been elected a director and Miss E. M. Young a special director.

Business Announcements

SIR THOMAS BORWICK has retired from the Plessey Company, Ltd., where he was general manager for the company in the Swindon Region.

RYDERS (LANCASHIRE), Ltd., Ocean Mill, Settle Street, Bolton, announces that its telephone number has been changed to Bolton 61451-2.

H. AND E. LINTOTT, Ltd., Horsham, a member of the Ayling Industries Group, states that its name has been changed to Lintott Engineering, Ltd.

CONTRACTORS PLANT HIRING COMPANY, Ltd., Leicester, has opened a new branch at Portland Chambers, 120-126, Portland Street, Manchester, 1 (telephone, Central 4822).

THE MINISTRY OF TRANSPORT has moved from Berkeley Square House to its new headquarters at St. Christopher House, Southwark Street, London, S.E.1 (telephone Waterloo 7999).

THE PYRENE COMPANY, Ltd., has acquired the business of Perfichrome, Ltd., of Brownhills, Staffordshire. It will be operated as a separate division of the company, and will be known as the Perfichrome division.

ALFRED HERBERT, Ltd., Coventry, has acquired 498-506, Chiswick High Road, London, W. Large-scale redevelopment is planned for the site, and the new premises will become the company's London headquarters.

ENGLISH STEEL CORPORATION, Ltd., Sheffield, states that the telephone number of its River Don Works, Grimesthorpe Works, Stevenson Road Works, Park Works, and Tinsley Park Works, has been changed to Sheffield 49071.

JOSEPH SANKEY AND SONS, Ltd., Wellington, Shropshire, states that the sales, sales promotion and southern area offices of the Vendo division are moving to its new London headquarters at GKN House, 22, Kingsway, W.C.2, on January 28.

THE VILLIERS ENGINEERING COMPANY, Ltd., Marston Road, Wolverhampton, has purchased the firm of John Roper and Son, Ltd., Upper Villiers Street, Wolverhampton. The business will continue without change other than an increase in production.

WESTFALISCHE METALL INDUSTRIE KG, HUECK AND CO., of Lippstadt, has acquired the exclusive right to manufacture and sell Napier " Spraymat " electrical system de-icing throughout West Germany. To enable Westfälische Metall Industrie to establish both manufacturing and servicing facilities, D. Napier and Son, Ltd., is to supply all necessary drawings, reports, technical information and assistance needed.

SIMMS MOTOR UNITS, Ltd., East Finchley, London, N.2, and the BENDIX CORPORATION, of Detroit, Michigan, U.S.A., announce that they have entered into an agreement under which Simms grant to Bendix an exclusive manufacturing licence and selling rights throughout the United States of America of its diesel fuel injection equipment. The Bendix Corporation has acquired at the same time non-exclusive selling rights of this equipment in Canada, Mexico and Brazil.

RADIATION, Ltd., has completed the co-ordination of all the Group's overseas activities by the formation of a new subsidiary company, Radiation International, Ltd. This company replaces Radiation Group Export Sales, Ltd., as well as the export divisions of the other subsidiaries including Ascot Gas Water Heaters, Ltd., and the electrical division of Radiation, Ltd. Mr. W. D. King, the Radiation chairman, has been appointed chairman of Radiation International, Ltd.; Radiation directors Messrs. A. J. Parker, F. P. S. Stammers and S. L. Pleasance are also on the board. In addition the board will include three export general managers, Mr. G. H. Behr, Mr. V. P. Marciandi and Mr. P. Wilkins.

BAKER PERKINS, Ltd., of Peterborough, which has a strong interest in the wrapping and packaging machinery industry through its wholly-owned subsidiary, the Forgrove Machinery Company, Ltd., and ROSE BROTHERS (GAINSBOROUGH), Ltd., have negotiated a plan for a merger. Subject to certain conditions, Morgan Grenfell and Co., Ltd., on behalf of Baker Perkins, Ltd., has signed an agreement with the owners of 53 per cent of the issued capital of Rose Brothers (Gainsborough), Ltd., with provision for the offer to be extended to all other stockholders. Under the proposed new organisation Mr. H. S. Ridley will continue as chairman of the company and all executive directors will continue in office. It is envisaged that Mr. A. I. Baker, chairman of Baker Perkins, Ltd., together with Mr. N. Mountain and Mr. R. H. Wilkins, directors of Baker Perkins, Ltd., and Mr. W. A. B. Brown, deputy managing director of the Forgrove Machinery Company, Ltd., will join the board of Rose Brothers (Gainsborough), Ltd.

Contracts

STANDARD TELEPHONES AND CABLES, Ltd., and SUBMARINE CABLES, Ltd., have received orders from the Management Committee of the Commonwealth Trans-Pacific Cable project for 8700 nautical miles of submarine telephone cable and 335 underwater repeaters. The total value of the order is 18 million pounds.

THE BRIGHTSIDE FOUNDRY AND ENGINEERING COMPANY, Ltd., has obtained an order valued at approximately £1,000,000 for bar rolling mills at the new Tinsley Park works, Sheffield, of the English Steel Corporation, Ltd. The mill will have an annual output capacity of over 100,000 tons of rounds, flats and other sections in alloy and special carbon steels.

J. L. KIER AND CO., Ltd., has been awarded a contract valued at £920,000 for the construction of a new quay and factory for Boulton and Paul, Ltd., at Lowestoft, Suffolk. The quay wall, approximately 800ft long, will consist of raking steel sheet piles driven on the foreshore. The contract also includes timber storage sheds, and reclamation. The scheme has been designed by Messrs. Posford, Pavry and Partners, consulting engineers.

EAGRE CONSTRUCTION COMPANY, Ltd., announces that it has secured a permanent way contract awarded in the region of £250,000 by the British Transport Commission, London Midland Region, for the installation of approximately 56 miles of plain track in running lines and sidings together with the design, fabrication and installation of some 350 sets of switches and crossings at Carlisle marshalling yard. The contract is programmed for completion in forty-eight weeks.

CONTINENTAL AFFAIRS

by Our Continental Editor

French "Bulb" Sets for Tidal and Low Head Power

No. I

Two large "bulb" turbo-alternator sets built by Etablissements Neyrpic and described in Part II of this article may be regarded as full-scale prototypes respectively for tidal and low-head power generation. Both sets have been in operation for some time. First, we explain briefly the concept of the Rance tidal power scheme, for the practical achievement of this concept depended upon the development of a turbo-alternator set with six modes of operation.

WHEN the first Deriaz turbines were installed at the Niagara pumped-storage power scheme in Canada, we pointed out that although considerable technical development had been evident over the years, the three basic types of water turbine—Kaplan, Francis and Pelton—had been unchanged for forty years or so, and the Deriaz machine (which is reversible and operates as a pump or a turbine) was the first major innovation in that period. At that time "bulb" turbo-alternator sets were in use, and were in process of evaluation, but it was not until a full-scale prototype for tidal power had been perfected, that another major innovation became evident. The "bulb" set at St. Malo has now been in use for about a year, generating power from the tides, and is noteworthy as the engineering device on which a new concept of tidal power hinges. Its novelty lies to a certain extent in its size—the set has a nominal capacity of 9MW—but more particularly in its versatility. It functions (*a*) as a turbine; (*b*) as a pump; and (*c*) as a spillway sluice, in either direction of flow; that is, it has six modes of operation, though the ranges of heads for modes (*a*), (*b*) and (*c*) are different. Why this versatility is necessary, and how it affects quite fundamentally the economy of tidal power, must first be explained. A brief résumé of the evolution of the "bulb" set will also be of interest before we describe the St. Malo set in detail. Another full-scale prototype, the application of which lies in low-head hydro-electric schemes on rivers, is also described. This set, at Beaumont-Monteux on the lower Isère, has only two modes of operation—as a turbine and as a sluice—and is, in effect, a Kaplan turbine with a horizontal shaft, and its alternator, &c., enclosed in a "bulb." Because of the potential economy of this prototype, the makers consider that application of the "bulb" set to low-head schemes is perhaps as important as the more spectacular application for tidal power.

Utilisation of Tidal Energy

In spite of the rapid exploitation of hydro-electric resources, which is characteristic of the mid-twentieth century, tidal power has remained untouched. Tidal power schemes have never been considered sufficiently attractive economically, because the quantity and availability of power, it has always been considered, were linked with the tidal cycle. That is, power became available on the falling tide about an hour later each day, and the quantity of power generated depended on whether spring or neap tides prevailed. Thus firm power could not be guaranteed, even though substantial capital cost might be entailed in building the scheme. The most notable case in this country is the Severn barrage project, which has been examined in great detail on more than one occasion* but has not been considered a good investment, for the reason just given. A notable attempt to overcome this difficulty was the Shishkoff thermal storage proposal† which linked the tidal-power turbine with a hydro-dynamic brake, from which steam was generated and stored until the "slack" tidal period, when it generated power in a steam turbine. Thus a continuous power output was achieved in the pilot plant, but at the cost of a complicated installation of plant.

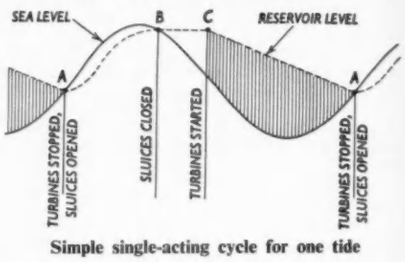
A complete break with these ideas has been made in considering the Rance scheme. Construction of this scheme, as was noted briefly in our issue of October 21 last, had just been started at that time. The theoretical background of the scheme has been largely developed by Monsieur Gibrat, who is Electricité de France's consultant for tidal power. His conception of the scheme, put very briefly, is as follows.

The tidal scheme is an element in the national power grid, and needs to be operated to give the maximum benefit to the grid. For instance, peak load power is of much higher value than power at other times, and equally it may be convenient, during the night for example, to consume surplus power. Six possible modes of operation at the tidal barrage can be utilised with this aim viz (i) direct generation, i.e. the reservoir flowing through the turbines towards the sea; (ii) "inverse" generation, i.e. the reservoir filling through the turbines; (iii) direct pumping into the reservoir; (iv) "inverse" pumping out of it; (v) and (vi) simply spilling water in either direction. "Thanks to these six modes," Monsieur Gibrat states, "it is possible, following the capacity of the network, to supply or receive power, and following the demand, to guarantee power during the peak hours or to produce energy with the sole aim of giving the maximum saving in coal at thermal stations, or of consuming by pumping to regulate consumption at night. Tidal energy thus demonstrates an extraordinary flexibility due to the extreme diversity of the possible cycles of operation." Thus constancy of output at all hours of the day is not sought, but the differing values of energy available at different times of the day are taken into account, and cyclical operation of the tidal scheme is adjusted accordingly.

This concept is best illustrated by considering various cycles. The first diagram shows a simple "single-acting" cycle. At point *A* the reservoir starts to fill; at point *B* the sluices are closed; at point *C* the turbines start to generate; and continue until point *A* is reached again. The simple single-acting cycle is also possible in the reverse sense, i.e. the turbines generate as the reservoir is filling. This cycle will yield less energy than the former, since the volume of water for, say, 1ft depth of the reservoir, will be greater at the top of the reservoir than at the bottom.

These two cycles can be combined into a "double-acting" cycle if it is mechanically practicable and economic to operate turbines for both directions of flow.

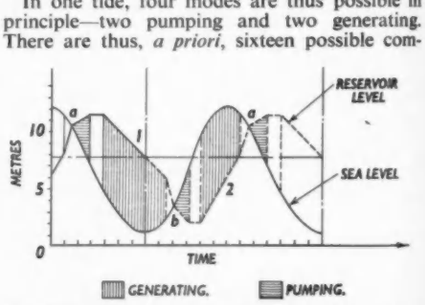
Now add to this the possibility of pumping in both directions of flow. The second diagram shows a possible cycle of events aimed at maximising the quantity of energy generated, for if it is possible to pump at the slack water periods there is an appreciable net gain in the quantity of power generated. Starting at the point just after high tide when reservoir and tide are at the same level, the waiting period *B C* of the simple cycle is replaced by a pumping period *a*; then a waiting period when the pumping head increases above a limiting value; then generation during the period 1, until the head falls to



Simple single-acting cycle for one tide

the minimum for generating; a period of simple emptying of the reservoir until tide and reservoir are again at the same level; a period of "inverse" pumping *b*; a period of "inverse" generation of power 2; and finally simple filling of the reservoir, to bring us to the starting point of the cycle again.

In one tide, four modes are thus possible in principle—two pumping and two generating. There are thus, *a priori*, sixteen possible com-



Maximum generation from one tide, with turbines operating in both directions of flow, and pumping in each direction respectively at each slack water

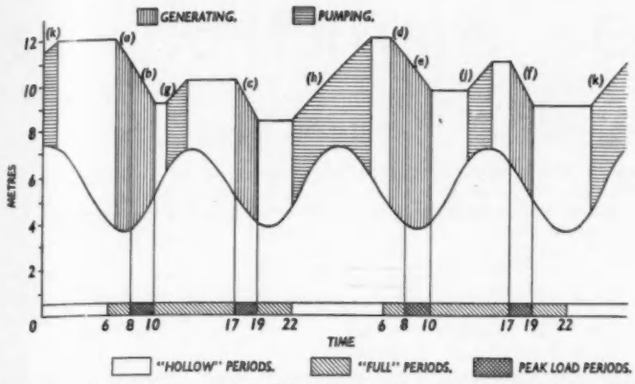
binations each representing a possible cycle for one tide. These can be set out, following Monsieur Gibrat's notation as follows:

	No pumping	Direct pumping	Inverse pumping	Two pumping periods
No generation ...	*Z*	*a*	*b*	*ab*
Direct generation ...	1	*a*1	1*b*	*a*1*b*
Inverse generation ..	2	*a*2	*b*2	*ab*2
Two generating periods	12	*a*12	1*b*2	*a*1*b*2

The cycle *Z* represents the case where hydro-electric stations are spilling, and the value of energy is thus zero throughout the tide; 1*b* represents a situation possible in a network with nuclear stations, for instance, where surplus energy needs to be consumed to avoid stopping a reactor. The cycle shown in the first diagram

* See THE ENGINEER, February 4, 1949, page 141, and February 11, 1949, pages 162, 165 and 171.

† See THE ENGINEER, September 26 and October 3, 1930, "The Shishkoff Hydro-Thermal Tidal Power System."



Peak load generation at equinoctial neap tides

Units generated :
(*a*) 10,500kWh
(*b*) 14,000kWh
(*c*) 14,000kWh
(*d*) 10,500kWh
(*e*) 14,000kWh
(*f*) 14,000kWh
Total 77,000kWh

Units consumed in pumping:
(*g*)+(*j*)= 19,000kWh
(*h*) 26,000kWh
(*k*) 16,000kWh
Total 61,000kWh

The tidal amplitude is 3·5m, as against 13·5m at spring tides. This cycle is single-acting with double pumping. The diagram is drawn for one set of 7MW maximum power, and thus generation is at full capacity in the four peak periods, *b*, *c*, *e*, and *f* of two hours each, and in addition 21,000kWh is generated in the "full" periods.

is 1, and in the second *a*1*b*2. Examination will show that there are eight " positive " i.e. practicable cycles possible, out of the theoretical sixteen—four single-acting (two without pumping and two with) and correspondingly, four double acting cycles. Except for the case of *Z*, the other possibilities are contradictory.

The simple case of a single tide is considered well adapted to analysis of the production of energy of constant value. With two tides, the variation in price between the peak, and what the French call literally the " full " and " hollow " hours, can be introduced. It is common to give relative values of 4 : 2 : 1 respectively to energy available in these three periods. A practical assessment is, however, only given completely if twenty-seven tides are considered, for this includes the week-end situation in the grid. Since there are sixteen possible cycles per tide, for two tides there are 16^2 possibilities (of which 104 are " positive ") and for twenty-seven tides 16^{27} possibilities (i.e. about 3×10^{32} of which about 3×10^{27} are " positive.")

Mathematical techniques (which involved quite lengthy research) were developed to solve this problem,* and to elucidate the relatively straightforward interpretations needed to operate the scheme.

Monsieur Gibrat stresses the extreme flexibility of the scheme, and hence its advantage to meet unforeseen situations in the grid, or developments which change the character of the grid. Two examples will illustrate the possibilities. The third diagram shows operation over two days comprising the shortest tides experienced in a four-year period. As will be seen the reservoir operates at levels always higher than the tide and approaching the spring tide maxima, and peak load output is maintained. The fourth diagram shows another case, in winter, of operation for peak load output with spring tides ; further details are given in the legends.

Evolution of the " Bulb " Set

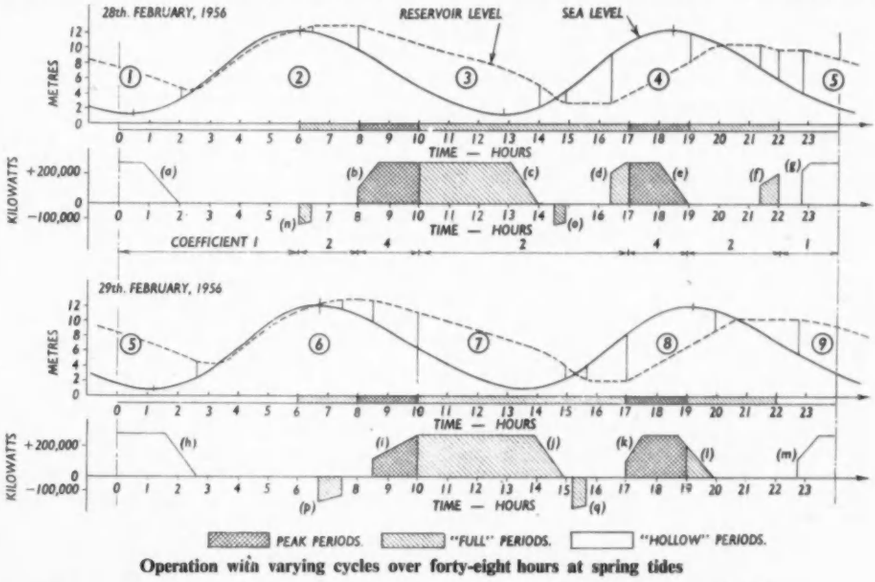
Further description of the Rance scheme, and the principal figures for its output installed capacity and so on, will be found in our earlier article, already referred to. Here we have aimed at giving sufficient explanation just to show how the theory of the scheme and the development of its prime mover are linked like two sides of a coin. Early design studies for the Rance scheme concentrated therefore on the practical aim of developing machine sets giving the maximum utilisation of the energy available at the site following the principles already described, at the most economic cost. A practical method of closing off the estuary when the barrage was constructed, was also investigated at this stage.

The use of " tubular " Kaplan turbines, i.e. with horizontal or slightly inclined shafts, each driving an alternator enclosed in a pier of the barrage around both sides of which water flowed to the turbine, first became prominent in certain schemes built in Germany during the war. Recent examples of this type of design are to be found at the power stations of the Moselle River ; sets of 4·5MW operating under a head of 5m to 7m are installed at one of these stations, as described in The Engineer, August 12 last. As in this case, it is common practice to have a coaxial gearbox between the turbine and alternator, so that the alternator runs faster than the turbine. A number of sets of this kind have been installed in France and Germany, and the French call them *groupes puits* or " pier-type " sets, to distinguish them from another similar design called, in French, *groupe bulbe-amont* or upstream bulb set.

In 1954 a notable step was taken with the installation of the first of these " bulb " sets at the Castet power station in the Pyrenees. These sets are of so-called " monobloc " construction ; that is, the bulb and turbine assembly was brought to the site in one piece and simply lowered into position, and fixed in its culvert. The alternator is asynchronous, and runs in oil which circulates as the coolant ; a description of this installation will be found in The Engineer, October 29, 1954, page 595. The capacity of each set is 810kW. The two sets described in detail in this article are in effect much larger developments of this idea, each retaining both the " upstream bulb " and the " monobloc " concepts. However it was not clear in the early stages of development that this would be so, and the earlier stages of evolution are not without interest.

The original researches on prototypes for the Rance scheme in 1951–53 led to the following proposals, which were made to Electricité de France by various manufacturers : a vertical-shaft set with elbow-shaped inlet and outlet ; a horizontal-shaft " pier-type " set ; a set with two adjacent contra-rotating runners, comprising two co-axial and opposed " tubular " sets, with the alternators in bulbs or as in the " pier-type "; an axial flow tubular set with polar wheel around the turbine runners ; an axial tubular set with the alternator in a downstream bulb, and the turbine runner positioned between the speed ring and the alternator ; a set identical with the last, but with two runners, each capable of acting either as a guide vane or runner according to the direction of flow. Generally, Kaplan runners were suggested, with movable guide vanes for operation as a turbine, and fixed for operation as a pump. Model tests on these proposals were made, and criteria for comparison between them worked out.

It was then decided to install two experimental sets at the Argentat power station, each of 14MW capacity. Each one utilised a hollow pier 18m in height, and was to function as a turbine for " direct " flow only, the head varying between 16·5m and 9·5m, and the nominal flow and speed being 100 cumecs and 150 r.p.m. respectively. Experimental pumping towards the downstream was also envisaged. One of these was a " pier type " set, but the other was a " downstream bulb." The latter consisted of a horizontal shaft Kaplan runner positioned on the downstream side of the concrete pier, from both sides of which water flowed to the turbine. Fixed and adjustable guide vanes were installed upstream of the runner. A shaft gave access to an enclosure in the pier on the upstream side of the turbine, in which the servo motor and thrust bearing were situated. The alternator was in a large steel-skinned " bulb " on the downstream side of the turbine, carried on three streamlined fins, the upper of which formed an access shaft. The alternator was cooled by circulation of air in a closed-circuit, using the exterior of the bulb as the cooling surface. At the same time, an



Operation with varying cycles over forty-eight hours at spring tides

Tides of February 28–29, 1956. Thirty-eight sets of 7MW each in operation. Tidal coefficient 95.

Comparative values of energy :

Peak periods (8 to 10 and 17–19 o'clock) ...	Four
"Full" periods (6–8, 10–17 and 19–22 o'clock)	Two
" Hollow " periods (0–6 and 22–24 o'clock) ...	One

The cycles aim at maximising the value of energy generated. The efficiency of generation is higher in "direct" flow (i.e. with reservoir emptying) which obtains in cycles 1, 3, 5, 7 and 9. In cycles 2 and 6, the most useful heads occur in " hollow " periods in the " inverse " (i.e. reservoir filling) direction of flow ; they are followed by " direct " cycles with energy coefficients of 2 and 4. Cycles 2 and 6 are thus aimed primarily at filling the reservoir for the next cycle. Energy generated in cycle 3 has a coefficient $\geqslant 2$; pumping at coefficient 2 is therefore justified preceding it. The same applies to cycle 4. But in cycle 5 the energy nearly all has a coefficient of 1, and pumping preceding it would be at coefficient 2, and would anyway be too long after the high tide to be carried out against a favourable range of heads.

Units generated : (*a*) 372,000kWh
(*b*) 441,000kWh
(*c*) 866,000kWh
(*d*) 160,000kWh
(*e*) 442,000kWh
(*f*) 273,000kWh
(*g*) 304,000kWh
(*h*) 600,000kWh
(*i*) 268,000kWh
(*j*) 1,220,000kWh
(*k*) 509,000kWh
(*l*) 154,000kWh
(*m*) 281,000 kWh
Total 5,890,000kWh

Units consumed in pumping :
(*n*) 54,000kWh
(*o*) 49,000kWh
(*p*) 114,000kWh
(*q*) 76,000kWh
Total 293,000kWh

* See *Bulletin* de la Société Française des Electriciens, May, 1953, and *Quatrième Journées de L'Hydraulique*, Société Hydrotechnique de France, Juin, 1956.

CONTINENTAL AFFAIRS *(continued)*

installation of two further experimental sets was undertaken at Cambeyrac power station. Here the following conditions were stipulated : capacity 5MW ; operation as a turbine for two directions of flow under heads varying between 10·75m and 3m, and a nominal flow of 5·5 cumecs ; pumping in either direction of flow, with pumping heads in the range 1m to 3m.

One of these sets was very similar in external shape to the " downstream bulb " set at Argentat (these two similar " bulb " sets both being in fact built by Neyrpic), but since there was no pier on the upstream side, it became, in effect, a runner built between two " bulbs." This set operated at 150 r.p.m., and owing to the different modes of operation stipulated, it had a thrust bearing capable of taking thrust in both directions, and blades on the turbine runner which could be turned through 230 deg. This large angle necessitated a correspondingly large and complicated servo-motor and governing mechanism, and also affected the adjustable guide vanes, each of which had an independent servo-motor. Further, the alternator cooling air was circulated through the fins carrying the alternator bulb, to a heat exchanger outside the bulb. This set has been in use since 1957.

The second set at Cambeyrac operates at 136·4 r.p.m. and was also basically a " downstream bulb " design, but with two adjacent turbine runners on adjacent but separate hubs. The alternator is powered by one or other of the runners, according to the direction of flow, or can be disconnected. In each direction of flow, the upstream wheel acts as the adjustable guide ring and the downstream one as the turbine proper, the blades of both being controlled by the governing mechanism. This set has an emergency sluice valve, which closes the annular culvert on the upstream side of the runners. This device is called an " iris valve " since it operates like the shutter of a camera, but giving an asymmetric opening or closure of the culvert according to the direction of rotation given to the water by the guide vanes. The alternator is overhung from the turbine shaft, and a self-ventilating cooling device dissipates the alternator heat losses through the skin of the bulb.

Valuable experience was gained from operating the sets at Argentat and Cambeyrac. It became clear that reduction in the overall size of the sets would give considerable advantage, the " downstream bulb " designs with their complicated mechanisms being excessively long. Thus the " upstream bulb " arrangement which had proved so successful on a small scale at Castet and various other installations, was modified to suit the relatively large sets needed for the Rance scheme. As in the Argentat and Cambeyrac experiments, the " upstream bulb " design was tried out with two full scale prototypes. The first of these, at Beaumont-Monteux, evaluated the design generally, and the complications of operation with flow in both directions were not introduced until the second prototype was built for installation at St. Malo. The simpler set at Beaumont-Monteux has a wide possibility of application, in its own right, to low-head schemes. For ease of description, however, we depart from the chronological sequence of events in the second part of this article to be published next week, and describe the St. Malo set first.

(To be continued)

Euratom Transuranes Centre

It has been decided to locate the third research centre of the European Atomic Community, the Institute for Transuranic Elements, at the German Nuclear Research Centre at Karlsruhe-Leopoldshafen. The relevant agreement was signed on December 21 between Euratom and the Federal Government. The cost of the institute which will be operated in conjunction with the German centre, will amount to about DM60,000,000 of which the Federation will contribute one-third.

Automatic Indexing Machine

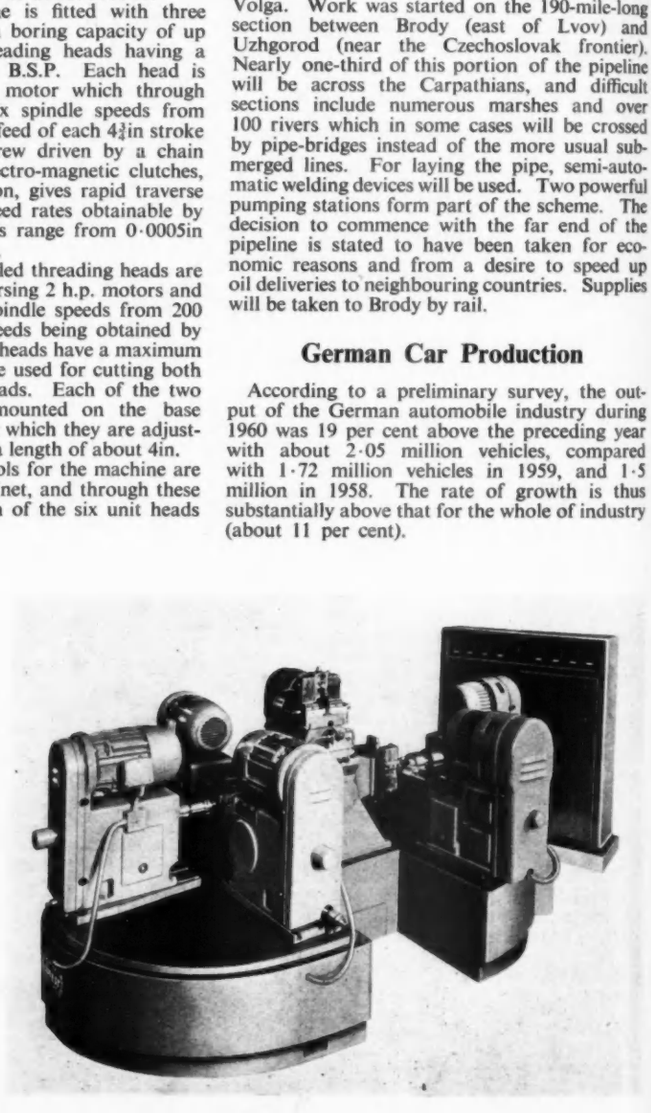
A SIX-SPINDLE automatic indexing machine designed to perform a number of operations simultaneously on three faces of a variety of components has been developed by the firm of Wilhelm Wiest of Plochingen, Germany, which is represented in this country by the Embassy Machine and Tool Company, Ltd., 248, Watford Way, London, N.W.4. As can be seen from the photograph we reproduce, the machine comprises a large base with a central four-station indexing work fixture and six unit heads, three on each side of the fixture.

The base casting has a machined top face on which the unit heads can be moved and positioned in accordance with the requirements of the components being handled. This base is 7ft 6in long by 5ft 5in wide and 18½in high, and is designed to give ease of access for the operator to the loading station of the central fixture and the grouped controls. The four-station indexing drum, which is indexed by a Geneva motion, is heavily supported on both sides close to the machining point and safety interlocks prevent faulty or double indexing. Self-centring jaws on the slides of the fixture are automatically opened and closed by control mechanism separate from that used for indexing purposes, and as each station reaches the loading position the jaws are opened automatically. The fixture assembly can be adjusted on the indexing drum and the clamping pressure exerted by the jaws varied from a few ounces to about 3000 lb.

The standard machine is fitted with three machining heads, with a boring capacity of up to 1¼in, and three threading heads having a capacity of up to 1½in B.S.P. Each head is driven by a two-speed motor which through stepped pulleys gives six spindle speeds from 700 to 2800 r.p.m. The feed of each 4¾in stroke spindle is by a lead screw driven by a chain wheel. A system of electro-magnetic clutches, with limit switch selection, gives rapid traverse or feed rates, and the feed rates obtainable by changing sprocket wheels range from 0·0005in to 0·018in per revolution.

The lead screw controlled threading heads are driven by two-speed reversing 2 h.p. motors and stepped pulleys giving spindle speeds from 200 to 500 r.p.m., slower speeds being obtained by changing pulleys. These heads have a maximum stroke of 3¼in and can be used for cutting both right- and left-hand threads. Each of the two types of unit heads is mounted on the base through sole plates along which they are adjustable by lead screws over a length of about 4in.

All the electrical controls for the machine are housed in a separate cabinet, and through these controls any combination of the six unit heads can be operated.



Unit head, six-spindle automatic indexing machine

Esch-sur-Sûre Dam

The recently completed arch dam on the River Sûre at Esch-sur-Sûre, Grand Duchy of Luxembourg, has a crown length of approximately 150m and a height of 50m. It spans the 100m-wide valley so as to form a reservoir of 62 cubic hectometres, which is filled from a catchment area in the Ardennes of 428 square kilometres. The chief purpose of the dam is regulation of the river which, throughout the year carries a variable flow of 60 to 100 cumecs. A small hydro-electric station working four hours per day produces 12 million kWh per annum. Because of its alkalinity, the water of the Sûre attacks concrete. In order to protect the structure, the waterface was coated with a synthetic rubber paint made by Société Chemaplast, 42, rue Pasquier, Paris (8e), based on Du Pont " Neoprene." Above the waterline and elsewhere on the airface, the dam was painted with a composition based on the same maker's " Hypalon " which is claimed to have superior resistance to sunlight as well as good weather and abrasion resistance. Contractors for the dam were Société C.O.E.H.B.A., 3, place des Etats-Unis, Paris (16e).

Eastern European Pipeline

The construction has begun of the first stretch of the " Friendship " oil pipeline connecting several Eastern European countries with the Volga. Work was started on the 190-mile-long section between Brody (east of Lvov) and Uzhgorod (near the Czechoslovak frontier). Nearly one-third of this portion of the pipeline will be across the Carpathians, and difficult sections include numerous marshes and over 100 rivers which in some cases will be crossed by pipe-bridges instead of the more usual submerged lines. For laying the pipe, semi-automatic welding devices will be used. Two powerful pumping stations form part of the scheme. The decision to commence with the far end of the pipeline is stated to have been taken for economic reasons and from a desire to speed up oil deliveries to neighbouring countries. Supplies will be taken to Brody by rail.

German Car Production

According to a preliminary survey, the output of the German automobile industry during 1960 was 19 per cent above the preceding year with about 2·05 million vehicles, compared with 1·72 million vehicles in 1959, and 1·5 million in 1958. The rate of growth is thus substantially above that for the whole of industry (about 11 per cent).

THE AMERICAN SCENE

By Our American Editor

The 1961 Cars

WITH a great fanfare, the American car industry recently launched its 1961 selling season. The National Automobile Show held in Detroit was the most lavish in history. Attractions included a speech by President Eisenhower, a musical revue, a commemorative stamp, and the premiere of a symphonic overture entitled " Wheels of Freedom" ! Indeed, so magnificent was the show that the new models it was designed to advertise seemed to suffer by comparison. To a public accustomed to seeing bigger and flashier cars roll off Detroit's assembly lines each year, the industry now is offering a product, which, in general, is smaller, cheaper and designed to sell on its merits as a machine rather than on appearance. Not since Henry Ford introduced the " Model T " has Detroit been so economy minded. The trend is unmistakable. The " Big Three " car makers have done extensive restyling, primarily to make their cars look more functional. Apparently the chief aim of the manufacturers in designing their 1961 models has been to make the ownership of an automobile less costly. Most of them have held to, or gone below, their 1960 prices. Moreover, they have called a halt to the horsepower race ; the new cars average 25 per cent less power than the 1960 models. They have built in a host of economy features and the warranties have been extended to cover a full year's operation. Finally, four new " compacts " have made their appearance alongside the six introduced in 1960.

To the potential American buyer, who for several years has been in a state of semi-revolt against Detroit's excesses in design, all this comes as good news. The industry itself and its 30,000 suppliers are not so sure. " If the compact idea leads to the 8,000,000 car year we have been dreaming about, it will be fine," says one Detroit executive, " but if it just means lower profit margins on 6,000,000 cars a year, we're in trouble." The parts suppliers tend to be even less enthusiastic. Some, certainly, expect to profit from the development of new products used in the 1961 models, but most view the trend toward compacts as one more affliction in a business which is already too competitive and too cyclical. Unless total car sales zoom to unexpected heights, a majority of parts manufacturers and suppliers look for lowered production in 1961. The small cars usually are sold with less optional equipment, such as power steering and automatic gear shifts, and they take less glass, rubber and steel. Furthermore, the drive towards cheaper cars inevitably leads to greater integration by the car makers ; to compete in price, they must turn out as many of their own components as possible.

Whatever the fate of the suppliers, the goal of the automobile makers for 1961 is to fend off the rising tide of imports and expand their market at least in proportion to the increase in the U.S. population. Their strategy is simple : offer better cars for less money. Detroit now recognises that the motor-car is no longer a status symbol ; people do not care about owning bigger, more luxurious cars than their neighbours. They just want efficient, comfortable means of transport ; elegant styling, to be sure, but not ostentation. The American car makers came around to this point of view reluctantly after seeing small, imported vehicles take a 600,000 unit bite out of their market in 1959. The conclusion was reinforced last year by the spectacular success of Detroit's own compacts, the sales of which approached 1,500,000. Says Phillip Monahan, Vice-President of General Motors : " We think we understand now what our customers want, and we are prepared to give it to them." If Mr. Monahan and the officials of other companies are correct in their analysis, what the public wants is more compacts. The four making their début this year—the Dodge " Lancer," the Pontiac " Tempest," the Oldsmobile " F-85 " and the Buick " Special "—are heralded as " true " compacts, not just trimmed-down versions of larger cars. The " Tempest," in fact, has a four-cylinder engine as standard equipment. As a class, the small vehicles now account for slightly more than 30 per cent of American passenger car output, and many in the industry believe they will take over at least 40 per cent of the market by the end of this year.

The spectacular rise of the compacts, however, is only part of the story. Other economy moves, too, are afoot. The Ford Motor Company's Mercury Division has unveiled a new six-cylinder car, the "Meteor." Along with the Dodge " Dart," it will compete in what was formerly the " low-priced " field occupied by Chevrolet, Ford, Plymouth, and the Studebaker " Hawk." Chrysler also has moved into a lower price field with its " Newport." A recent study of prices showed that, on the average, American motorists will be paying 500 dollars less for 1961 passenger cars than they did for 1959 models. While most of the decline stems from the introduction of compacts, the prices of many standard-size cars also have been cut this year. Lower prices notwithstanding, the new models incorporate many engineering improvements calculated to make them ride better and last longer. For example, every company in the industry now is taking precautions to prevent the underbodies from rusting away. The Chrysler Corporation has a twenty-four-step treatment which includes two primer coats and two coats of enamel for all surfaces subject to corrosion. Ford has placed a " splash apron " inside the front fenders and is galvanising some underbody areas to accomplish the same purpose. Thus, there is a concerted drive to improve the quality of the American automobile. While rustproof underbodies may not have as much appeal in the showroom as a grinning radiator grille or an upswept tail fin, they, nevertheless, help to sell the cars. The manufacturers are similarly preoccupied with mufflers, or silencers, which tend to wear out every two or three years, particularly on cars with dual exhausts. Since the latter do not get as hot as those in earlier cars, acids are not vaporised and the metal consequently is eaten away. Most companies have resorted to aluminium or zinc coatings, but American Motors has gone a step further and uses a ceramic coating, developed in co-operation with the Walker Company of Toledo. The ceramic muffler is guaranteed for as long as the original owner keeps the car. Another American Motors " first," the acoustical topliner, was developed in co-operation with the Johns-Manville Corporation. Normally, the fabric interior ceilings of cars are sewn in place by upholsterers. The new liner, in contrast, is a rigid, preformed unit made of fibreglass, which can be snapped into place by two assembly-line workmen. It saves labour, allows passengers slightly more head-room, deadens noise, and gives a feeling of greater spaciousness.

One reason for American Motors' phenomenal recent success in bucking the " Big Three " is its policy of close co-operation with parts manufacturers. When an improved component such as the ceramic muffler or the acoustical topliner is developed by a supplier, the firm is willing to buy it exclusively from him. This policy gives American Motors, which lacks extensive laboratory facilities of its own, the benefit of strong research and development programmes carried on by other firms. By contrast, the " Big Three " usually insist on alternative sources for any parts they buy, and frequently put their suppliers out of business by deciding to do their own manufacturing. A case in point is the new alternator, which replaces the d.c. generator on every 1961 Chrysler car, from the " Valiant " to the " Imperial." Previously, all Chrysler generators, as well as its voltage regulators and distributors, were supplied by Electric Autolite, but the alternator and most distributors now are being made by Chrysler. However, Chrysler must be credited with a long step forward in developing the alternator. For one thing, the alternator is almost 10 lb lighter and much smaller than the generator. For another, its brushes last two or three times as long, thus cutting maintenance costs. Most important of all, it generates more current at low engine speeds ; even when the motor is idling, it puts out up to 10A, whereas an ordinary d.c. generator yields no current at all at such a time. This is a most desirable feature for stop-and-go winter driving, when all the electrical gadgets on a car often are operating at once, thus putting a heavy drain on the battery. At General Motors, the most radical departure is the " trans-axle " on the new Pontiac " Tempest." Although the engine is in the front, the transmission is mounted in the rear, just ahead of the differential. The two are connected by a flexible drive shaft, housed in a curved but rigid torque tube. This arrangement enabled the designers virtually to eliminate the bothersome floor tunnel which runs through most cars. Moreover, the transmission in the rear gives a better distribution of weight and improved riding and handling. Most

THE AMERICAN SCENE *(continued)*

General Motors cars which have factory-installed air conditioning now utilise the new Eaton "Tempatrol" fan drive, which controls the speed of the radiator fan thermostatically. In winter, the fan remains idle until the engine temperature reaches a specified level, while on a hot day it gives maximum cooling immediately. Though it is particularly useful in an air-conditioned car, the Eaton Company expects it to come into almost universal use in the 1962 models.

The Ford engineers claim "one of the most significant improvements in the history of the six-cylinder engine" with their new silent lash rocker arm. It is a valve tappet system which is said to eliminate the need for frequent tappet adjustments and to give quieter, more stable performance. Anticipating California's smog control regulations, Ford also has devised a method of disposing of "blow-by" gases—the unburnt hydrocarbons which escape through the crankcase. They are trapped and fed through the carburetter again into the combustion chambers. Chrysler has a similar device, which it is installing only on cars to be sold in California. As a stimulant to sales, probably the major development of the year is the chassis which requires no—or at least very infrequent—lubrication. The Ford Motor Company claims that its Mercurys and Lincolns need greasing only every 30,000 miles, while Cadillac insists that the factory lubrication is good for the life of the car. All grease fittings have been replaced by plugs, which in the Cadillac are said to be merely precautionary and in the Fords permit servicing when necessary. In the "lube-free" chassis, dirt is kept out of bearings and joints by tough plastic seals and liners, and the cars employ a grease to which is added 3 per cent molybdenum disulphide. Oils and greases containing the additive have been commercially available for some time, but so far, the grease additive application has not been a major market for molybdenum.

To the automotive suppliers, undoubtedly the most significant development in the 1961 models is the greater use of aluminium, to save weight and fuel. The new cars, according to a study by Kaiser-Aluminium, will carry an average of 62·1 lb, against 54·5 lb on the 1960 models. The biggest breakthrough is in the use of aluminium engine blocks. Pioneered last year by the Chevrolet "Corvair," the new block is standard equipment this year on all "Ramblers," the Buick "Special" and the Oldsmobile "F-85." An optional engine for the "Tempest" also is aluminium, and the metal will be tested in about 10 per cent of the Chrysler "Lancers," "Darts" and Plymouths. Since each engine uses up to 125 lb, and the compacts are expected to be the best sellers in 1961, Detroit may use about 380 million lb of aluminium during the model year. Reynolds Metals will supply the aluminium to General Motors under "hot metal" contracts. The molten metal is poured directly from reduction pots, an arrangement which is said to reduce significantly the cost of the new engines. Kaiser Aluminum is supplying the metal for the "Rambler" blocks to the Doehler-Jarvis Division of National Lead, which die-casts them for American Motors at its Toledo plant. Chrysler is buying its aluminium under a "cold metal" contract with Aluminium, Ltd., of Canada. The fact that three new cars are to have aluminium engine blocks does not mean that the entire automotive industry necessarily is going in that direction. For the moment, Ford is standing by the cast iron block for all its engines, General Motors is using the traditional metal in all its heavier cars, Studebaker-Packard remains unconvinced of the need for a change, and Chrysler is undecided.

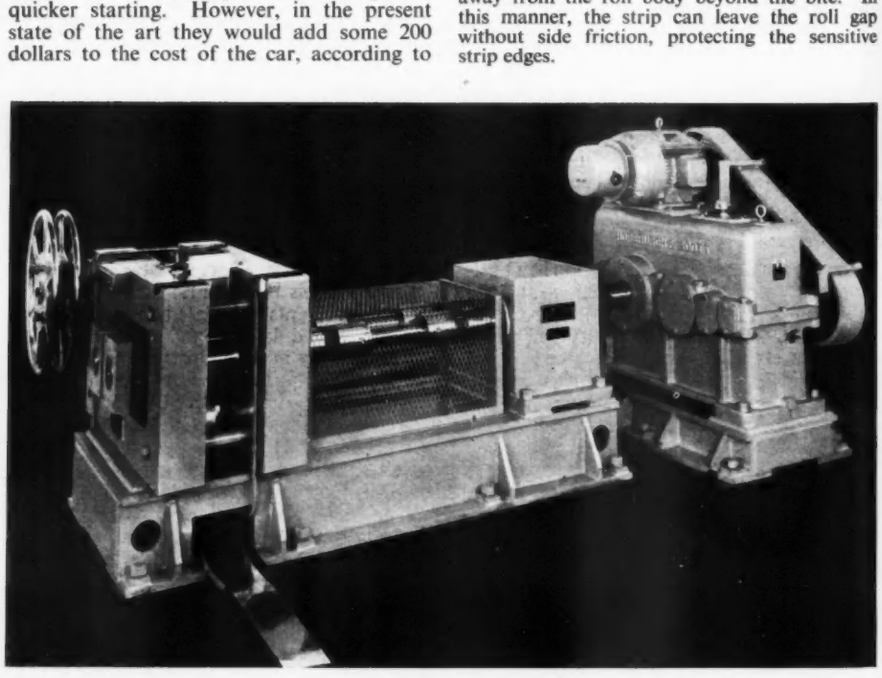
What of further technical developments in Detroit? The most likely future possibility is a miniature car, to compete with the Volkswagen and the Renault "Dauphine." Ford confirms that it is considering the introduction of such a car. If the project is approved, the tentatively-named "Cardinal" would be built at least partly in Europe, because of the lower production costs there. Ford of Germany has developed a new car in the VW-Renault class, to be introduced in European markets soon. Other developments, too, loom on the horizon. A few years ago there was much talk in Detroit about the gas turbine engine. Engineers, however, expect no workable gas turbine for automobiles before 1970. The fuel cell, which converts hydrogen, propane or other fuel directly into electric power in what amounts to a continuously-fed battery, may become applicable to motor-cars before the gas turbine. Electric Autolite recently stepped up its research and development programme on fuel cells. Another possibility is the Wankel engine, developed jointly by NSU Werke in Germany and Curtiss-Wright in America. With only one moving part, the engine is expected to yield far greater power, in proportion to its weight, than a reciprocating motor. Although a Wankel engine has been used to drive an experimental NSU "Prinz," it is expected that development work will take another year. Fuel injection systems, too, could be installed on passenger cars to-morrow if the experts were convinced of the demand. Replacing the carburetter, they pump exactly metered quantities of petrol into the cylinders, giving up to 20 per cent greater fuel economy. They also eliminate vapour locks and permit quicker starting. However, in the present state of the art they would add some 200 dollars to the cost of the car, according to Simmonds Precision Products, Inc., which foresees an increasing use of the devices in heavy trucks in the next few years, but looks for no large-scale passenger car market until about 1965. The automobile manufacturers themselves, secretive as always, give no hint of what they have in mind for the 1962 models. However, if the present engineering improvements win the expected customer acceptance, it is a foregone conclusion that Detroit will step up its policy of "more quality under the bonnet."

Production of Strip from Powder

The Naeser-Zirm powder rolling method of thin-gauge strip production has been brought within reach of the smaller metal works and pilot plant by the recent development of a low-cost horizontal compacting mill with patented edge control. While the technique is particularly well suited to the production of nickel strip for the electronics field, it is also being employed successfully in the manufacture of nuclear fuels, stainless steel filters and copper radiator stock.

Designed and built by the Loma Machine Manufacturing Company of New York, the new machine employs 10in diameter by 8in wide rolls made of alloy tool steel and hardened to Rockwell C-64. The two rolls are mounted side by side, unlike those of a conventional mill, which are one above the other. In operation, fine metal powder is continuously fed into the mill through a hopper equipped with flow controls. Green strip leaves the mill on an exit chute at speeds varying from 12·5ft to 50ft per minute and is passed continuously into a protective atmosphere sintering furnace. Subsequently, it is given a reduction on a two-high mill and further passes on a four-high cold mill of conventional design. The purity of the compacted strip is limited only by the purity of the original powder, and 99·9 per cent metal purity at 100 per cent strip density is readily obtainable.

An interesting aspect of the new compacting mill is its Heck edge control device comprising a pair of specially designed elastic discs that rotate at the roll edges to form the strip to an exact width dimension, with a perfectly square edge, without any notches or cracks. One set of pressure rollers forces the discs against the rolls at the bite, while another set lifts the discs away from the roll body beyond the bite. In this manner, the strip can leave the roll gap without side friction, protecting the sensitive strip edges.



Loma horizontal compacting mill for the production of nickel strip from powder metal

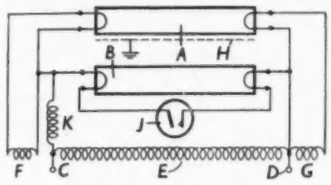
BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

ELECTRIC LIGHTING

55,937. March 17, 1958.—FLUORESCENT LAMP CIRCUITS, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. (*Inventor : Julius Cates.*)

This invention relates to circuits for operating a.c. low-pressure mercury vapour electric discharge lamps in circumstances in which it is important that light should not fail when one of the lamps fail. Such circumstances arise, for example, in lighting traffic ways in tunnels, or in installations where lighting is required for signalling to or directing traffic. In principle, the circuit operates two lamps, of which the standby lamp is started by a glow starter. On connection to the supply, the electrodes of the first lamp are heated by the current from the electrode heating circuit. The supply voltage appears across the discharge paths of both lamps, and the starting circuit in the second lamp is energised. Because of the delay in starting of the second lamp due to the time required for the bimetallic element of the glow starting switch to become heated, the first lamp will normally start first, and as soon as the discharge in the first lamp is established, the voltage across the second lamp and its starting circuit falls to the running voltage of the first lamp, being insufficient to operate the glow switch and cause the second lamp to start. Referring to the drawing showing one form of the circuit, this is designed to operate a main



No. 855,937

lamp *A* and a stand-by lamp *B* from an alternating current supply to be connected between the terminals *C* and *D*. In operation, when the supply voltage is applied, current flows through the primary winding *E* of the starting transformer for lamp *A* and electrode heating current is supplied to the electrodes of that lamp by the secondary windings *F* and *G*. The lamp thereupon starts, starting being facilitated by an earthed starting electrode *H*. Should the lamp *A* for any reason fail to start, the supply voltage is maintained across the glow switch *J* for a sufficiently long time for the contacts of this switch to close and re-open, thus starting the lamp *B*. Similarly if the lamp *A* should fail whilst operating, the voltage across the glow switch will rise and cause it to operate so as to start the lamp *B*. In a second embodiment winding *E* is connected in series with the ballast *K* instead of being connected directly between the terminals *C* and *D*. The result is that when the lamp *A* is in operation the voltage across winding *E* falls to the normal lamp operating voltage, reducing the heating current supplied by the secondary windings to the lamp electrodes. A third embodiment, described in the specification, is for operating lamps of lower power, inductor *K* being replaced by an inductor and capacitor in series.—*December* 14, 1960.

INSTRUMENTATION

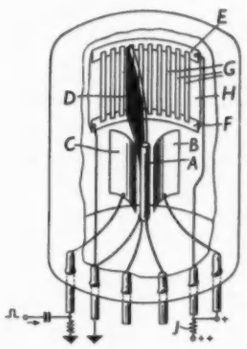
856,383. July 31, 1956.—INDICATING INSTRUMENTS, Bailey Meters & Controls, Ltd., Purley Way, Croydon, Surrey. (*Inventors : Philip Cowlin and Eric John Hook.*)

When remote indication is required of the position of an instrument index relative to a selected position on the scale, it is difficult in some conditions to show on which side of the position the index lies. When, as is usually the case, the index is mounted on a lightweight moving element, such as the pointer of a galvanometer, it is not practicable to use a remote indicating means which would exert any appreciable force on the index or the parts moving with it. According to the present invention, therefore, a light-control vane moves with the index and effects darkening (or alternatively illumination) of two photo-electric cells in sequence as the index passes the preselected location, this sequence depending on the direction of travel. The cells are connected in a circuit which includes a relay, the arrangement being such that when the cells are darkened (or illuminated) in one sequence this relay assumes a first state ; and when the cells are darkened (or illuminated) in the reverse sequence the relay assumes a second state. Thus, by means of the relay, means are provided for a remote indication and/or control when the index is to one side of the selected location, and for a different indication and/or control when the index is to the other side of that location.—*December* 14, 1960.

ELECTRONICS

857,339. August 9, 1957.—COUNTING TUBES, Philips Electrical Industries, Ltd., Spencer House, South Place, Finsbury, London, E.C.2.

This invention relates to counting tubes having a ribbon-shaped electron beam, which can be deflected and held in different positions, and relates particularly to the collecting electrode for the electron beam. A simple construction is possible by collecting the electrons of the beam on a collecting electrode which is preferably applied to the tube wall. Referring to the drawing of such a tube, cathode *A* and deflection plates *B* and *C* are housed in the bulb, which electrodes produce a ribbon-shaped electron beam *D*. The beam strikes a collecting electrode consisting of layers in the form of strips *E* and *F* of good conductivity, which are connected to each other by straps *G* of a substance of which the conductivity increases strongly upon electron impact, in this example, zinc sulphide. The strips and straps may be arranged on a slightly conductive wall layer *H*, which serves to conduct away electrons falling at the side of the straps. The strip *E* is connected through a resistor *J* to a positive voltage of a few hundred volts and the strip *F* is connected to the cathode. In the position shown, the beam indicates the number 7, there being ten straps. Deflection plate *B* is connected externally of the tube to the strip *E*. The beam falls partly to the left-hand side of the "7" strap and partly on that strap. Consequently, this strap has a low resistance, so that the current from the strip *E* to the strip *F* increases strongly, and the



857,339

voltage of the strip *E* drops owing to the voltage drop across the resistor *J*. The beam is held in this position, since the voltage of the strip *E* and hence that of the deflection plate *B* drops, when the beam strikes a larger part of the strap, so that it is again deflected to the left-hand side, whilst the reverse takes place when the beam moves further to the left, i.e. away from the strap. By supplying a positive pulse to the plate *C*, the beam can be moved to the next following strap. A modification of these arrangements is shown in the specification, in which the strips and straps are arranged one behind the other, viewed in the direction of travel of the electrons.—*December* 29, 1960.

ELECTRICAL ENGINEERING

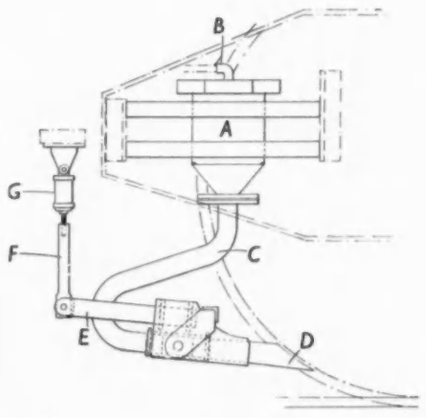
856,071. July 14, 1958.—COOLING OF ELECTRICAL GENERATORS, "Licencia" Talalmanyokat Ertekesito Vallalat, 10, Jozsef nador ter, Budapest V, Hungary.

This specification describes a method for artificial cooling of electrical generators making use of steam jet ejector equipment which takes steam from a bleeding point on the turbine. The heat exchanger of the alternator gas cooling system is in two parts, one always supplied with natural cooling water and the other with condensate from an evaporator in communication with the condenser of the steam turbine. If the generator temperature exceeds a permitted maximum, steam bled from the turbine sets one or more ejectors in operation, which compress the steam returned to the condenser from the evaporator of the cooling system. This causes part of the circulating condensate to evaporate, causing the condensate to cool off and to be pumped back at this lower temperature to the heat exchanger. At the same time a suitably-controlled valve allows make-up water to pass from the condenser into the evaporator. The system claims economy on the two points of omitting a special condenser by utilising the normal installed equipment of the steam turbine, and operating the ejectors with steam taken from an existing bleeding point.—*December* 14, 1960.

RAILWAY VEHICLES

857,246. December 23, 1958.—RAILWAY VEHICLES, Gresham and Craven, Ltd., Craven Iron Works, Ordsall Lane, Salford 5, Lancashire. (*Inventors: Gordon Williams and Albert Reidinger.*)

This invention relates particularly to methods and apparatus for the application of sand, grit or abrasive material to improve the adhesion between the wheels of railway vehicles and the rails. One embodiment of apparatus is described with reference to the accompanying drawing. Mounted on the vehicle frame is an hermetically sealed canister *A* which has a conical lower part and is filled with anti-slip material. It has been found that the most suitable paste for this purpose is a compound of clean sharp sand, water, glycerine and a bonding agent such as starch derivatives and resinous compounds. The constitutents are mixed in such proportions as to give a paste having about the same consistency as toothpaste. A pipe *B* leads from the upper portion of the canister to an air or steam pressure control valve in the driver's cab. A pipe *C* leads from the base of the canister and is connected by a length of flexible hose to a nozzle *D*. The nozzle is pivotally mounted to a post fixed to the unsprung structure of the vehicle by a bracket. One end of a lever *E* is also connected to the bracket, the other end being pivotally connected to connecting-rod *F*. The rod *F* is connected to a sprung piston in a cylinder *G* which is



No. 857,246

so arranged that when air or steam pressure is applied to a canister through the pipe pressure is simultaneously applied to the piston in the cylinder. This piston overcomes the resistance offered by the spring and depresses the rod *F* and causes the nozzle to pivot and move into close proximity with the tread of the tyre of the driving wheel. Pressure in the canister forces the anti-slip compound down the pipe, and through the nozzle onto the tyre. The arrangement shown is designed to apply a compound whose viscosity is so great that, when the pressure is cut off from the canister and the cylinder, thereby withdrawing the nozzle from close proximity with the wheel, the paste ceases to flow. However, should less viscous mixtures be used a simple valve is located at the base of the canister to cut off the flow of compound.—*December* 29, 1960.

Catalogues and Brochures

CRODA, Ltd., Cowick Hall, Snaith, Goole, Yorkshire.—Techanical data sheet on priming paint P.P. 138 (calcium plumbate).

GORDON AND GOTCH (SELLOTAPE), Ltd., 8-10, Paul Street, London, E.C.2.—Pocket information booklet entitled "Electrical Taping."

BROOKS AND WALKER, Ltd., 47, Great Eastern Street, London, E.C.2.—Leaflet giving details of the "PAV" 6in fine precision universal vernier caliper gauge.

THE TRENT VALVE COMPANY, Ltd., 47, Great Eastern Street, London, E.C.2.—Valve catalogue containing over 130 pages of illustrations and technical data.

TURNER BROTHERS ASBESTOS COMPANY, Ltd., Rochdale.—Publication No. D4 covering a range of "Duraglas" glass-fibre woven tapes for electrical insulation.

THE EQUIPMENT AND ENGINEERING COMPANY, Ltd., 2 and 3, Norfolk Street, London, W.C.2.—Material describing the "Simplex" centre hole hydraulic jacking equipment.

IMPERIAL ALUMINIUM COMPANY, Ltd., P.O. Box 216, Birmingham, 6.—Booklet containing details of the Mark III series of "Impalco" aluminium alloy extruded lorry body sections.

HERBERT MORRIS, Ltd., P.O. Box 7, Loughborough—Book No. 242 illustrating some of the complete mechanical handling the company has installed for a variety of different industries.

BRITISH ROPES, Ltd., Doncaster.—Publication No. 214, issued by the company's wire rope advisory and technical service department, entitled "Multi-Strand Non-Rotating Ropes: Installation, Handling, Maintenance, Inspection."

AB SVENSKA METALLVERKEN, Manufaktur-Avdelningen Västeras, Sweden.—"SM Sintermetall." Information M.9. Gives design examples of components made of sintered metal and lists the properties of alloys manufactured by the company.

J. AND J. DYSON, Ltd., Stannington, Sheffield.—Illustrated catalogue of casting pit refractories and special fireclay shapes for the steel industry. This deals with the products of several works, and includes cements and plastic refractories as well as moulded shapes.

FRIED. KRUPP SCHMIEDE UND GIESSERET, Essen, Altendorfer Strasse 100, German Federal Republic.—"Krupp-Rolls." Illustrated pamphlet describing the evolution of the rolling process as well as present day techniques of rolling, roll manufacture and maintenance, causes of damage, reconditioning, special purpose rolls, and the company's manufacturing programme.

IMPERIAL ALUMINIUM COMPANY, Ltd., P.O. Box 216, Witton, Birmingham, 6.—Technical data brochure giving details of aluminium and aluminium alloys. It is divided into four sections dealing with commercially pure aluminium, non-heat-treatable alloys, heat-treatable alloys, and miscellaneous alloys suitable for use as brazing materials or for general machining. For each material the brochure lists the characteristics and typical uses, specifications, chemical composition, physical and mechanical properties, and heat treatment details.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., Jan. 30.—NORTH WEST LONDON BRANCH: Compass Hotel, Watford, "Static Switching Control Systems," J. N. Fletcher, 7.45 p.m.

Wed., Feb. 1.—HALIFAX BRANCH: Crown Hotel, Horton Street, Halifax, "Instrumentation," D. M. Everett, 7.45 p.m. ★ NORTH LONDON BRANCH: Wood Green Civic Centre, Town Hall, Wood Green, N.22, "The Application of Electric Furnaces to the Heat Treatment of Metals," L. G. Palethorpe, 8 p.m. ★ SOUTH EAST LONDON BRANCH: Eltham Green School, Queenscroft Road, Eltham, S.E.9, "Relays and Control Circuits," W. L. Stern, 7.45 p.m. ★ PRESTON BRANCH: R.A.F.A. Club, East View, Preston, "The Architect and the Engineer in Building Construction," R. Booth, 7.30 p.m.

Thurs., Feb. 2.—BRIGHTON, HOVE AND DISTRICT BRANCH: New Imperial Hotel, First Avenue, Hove, Sussex, "Motor Control Centres," N. E. Steptoe, 7.30 p.m.

Fri., Feb. 3.—LIVERPOOL AND DISTRICT BRANCH: Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, "Static Switching Control Systems," J. N. Fletcher, 7.30 p.m. ★ STOKE AND CREWE BRANCH: Royal Hotel, Crewe, "Electrical Catering Equipment," H. Meadowcroft, 7.30 p.m.

Sat., Feb. 4.—MANCHESTER BRANCH: Engineers Club, Albert Square, Manchester, "Heavy Industrial Control Gear," C. V. Curran, 7.15 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Feb. 1.—RADAR GROUP: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "A Fast Electronically Scanned Receiving System," D. E. N. Davies, 5.30 p.m.

Thurs., Feb. 2.—NORTH WESTERN SECTION: Reynolds Hall, College of Technology, Manchester, "The Manufacture of Television Tubes," P. Funnell, 7 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Tues., Feb. 7.—NORTHERN REGION: George Hotel, Huddersfield, Discussion on "Planned Plant Maintenance," 2.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Jan. 30.—BIRMINGHAM CENTRE: Regent House, St. Phillip's Place, Colmore Row, Birmingham, "Visual Perception," R. G. Hopkinson, 6 p.m.

Wed., Feb. 1.—EDINBURGH CENTRE: Y.M.C.A. Social Room, 14, South St. Andrew Street, Edinburgh, "Lighting in Industry in the Soviet Union," E. H. Norgrove, 6.15 p.m. ★ NEWCASTLE UPON TYNE CENTRE: Room B7, Percy Building, King's College, Queen Victoria Road, Newcastle upon Tyne, 1, "Hospital Lighting," G. R. N. Chalmers, 6.15 p.m.

Thurs., Feb. 2.—GLASGOW CENTRE: British Lighting Council, 29, St. Vincent Place, Glasgow, C.1, "Office Lighting," L. H. Hubble, 6.30 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, Jan. 27.—MERSEYSIDE AND NORTH WESTERN SECTION: Central College of Further Education, Barrow-in-Furness, Joint meeting with the Barrow Association of Engineers, "Oil Fuel Burning," A. H. Skinner, 7.30 p.m.

Wed., Feb. 1.—JUNIOR LECTURE: Kingston Technical College, Kingston-on-Thames, "Gas Turbines," F. O. J. Otway, 2.30 p.m.

INSTITUTE OF METALS

Thurs., Feb. 2.—BIRMINGHAM LOCAL SECTION: College of Technology, Gosta Green, Birmingham, Students' Evening, Conversazione and Exhibition, 6.30 p.m. ★ LONDON LOCAL SECTION: 17, Belgrave Square, London, S.W.1, "The Development of Some New Bearing Materials," P. G. Forrester, 6.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Feb. 1.—Lecture Theatre, 61, New Cavendish Street, London, W.1, "Radiation Resistant Greases—A Study of Thickeners and Antirads," W. Crawford, and D. B. Dox, 5.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., Feb. 2.—Institute of Marine Engineers, Memorial Building, 76, Mark Lane, London, E.C.3, "A New Conception in Cooling Tower Design," C. Munters and L. Lindqvist, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Jan. 30.—SCOTTISH CENTRE: North British Hotel, Edinburgh, "Servicing in the Field," 7.30 p.m.

Wed., Feb. 1.—WESTERN CENTRE: Smiths Assembly Rooms, Bath, "A Review for the Selection, Specification and Design of a Commercial Vehicle," E. B. H. Elsbury, 7 p.m.

Mon., Feb. 6.—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow, "Recent Developments in Head Lighting," J. H. Nelson, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Wed., Feb. 1.—MIDLANDS BRANCH: Midland Hotel, Birmingham, "Diffusivities in Aqueous Solution," F. H. Garner, and P. J. Martin, 6.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Jan. 31.—Great George Street, Westminster, London, S.W.1, "An Approach to the Design of Tall Steel Buildings," Jacques Heyman, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Jan. 30.—ARBORFIELD DISTRICT MEETING: Unit Cinema, 3 (Tels.) Training Bn., R.E.M.E., Arborfield, Berks., "Automatic Trunk Dialling," H. E. Francis, 7 p.m. ★ SOUTH EAST SCOTLAND SUB-CENTRE, GRADUATE AND STUDENT SECTION: Canteen, South of Scotland Electricity Board, Dewar Place, Edinburgh, "The Application of Electronics to Chemical and Gas Analysis," G. J. Geis, 7.30 p.m.

Tues., Jan. 31.—NORTH-WESTERN SUPPLY GROUP: Engineers' Club, Manchester, "A Basis for Short-Circuit Ratings for Paper-Insulated Cables up to 11kV," L. Gosland and R. G. Parr, and "Short-Circuit Ratings for Main Cables," G. S. Buckingham, 6.15 p.m.

Mon., Feb. 6.—SOUTH MIDLANDS CENTRE: James Watt Memorial Institute, Birmingham, "Development of H.V. Air-Break Circuit Breakers with Insulated-Steel Plate Arc Chutes," F. S. Fay, J. A. Thomas, D. Legg and J. S. Morton, 6.30 p.m.

Tues., Feb. 7.—SOUTH-EAST SCOTLAND SUB-CENTRE: Carlton Hotel, Edinburgh, "A Visit to South Africa," M. G. Say, 7 p.m. ★ NORTH MIDLAND CENTRE: Leeds and County Conservative Club, South Parade, Leeds, 1, Third Hunter Memorial Lecture, "The Application of Electronics to the Electricity Supply Industry," J. S. Forrest, 6.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Jan. 31.—39, Elmbank Crescent, Glasgow, Hugh Macmillan Memorial Lecture, "The Interdependence of Engineering and Chemistry," Sir Alexander Fleck, 6.30 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Thurs., Feb. 2.—LONDON BRANCH: 38, Portland Place, London, W.1, "Some Aspects of the History of Engineering Drawing Leading to Drawing Standardisation," P. J. Booker, 7 p.m.

Mon., Feb. 6.—NORTH-EAST BRANCH: New Lecture Theatre, Rutherford College of Technology, Northumberland Road, Newcastle upon Tyne, 1, "Precision Investment Casting," N. Walker, 7.15 p.m.

INSTITUTION OF ENGINEERS-IN-CHARGE

Wed., Feb. 8.—Kent Room, Caxton Hall, Westminster, S.W.1, "Process Steam Utilisation," W. N. Barber, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Thurs., Feb. 2.—YORKSHIRE AND LINCOLNSHIRE BRANCH: Griffin Hotel, Leeds, "Design and Execution of Road Improvements in Urban Areas," S. G. Wardley, 7 p.m.

Fri., Feb. 3.—LONDON BRANCH: Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Lessons Learned on the Design, Construction and Maintenance of Motorways—(iii) From the Contractor's Angle," W. Kirby Laing, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Sat., Jan. 28.—LONDON GRADUATES' BRANCH: 1, Birdcage Walk, Westminster, London, S.W.1, Annual Lecture, "Engine Research in the Oil Industry," C. G. Williams, 3 p.m.

Tues., Jan. 31.—AUTOMOBILE DIVISION: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Quality Control and Reliability," opened by F. Nixon, 6 p.m. ★ DERBY A.D. CENTRE: Visit to Rolls-Royce, Ltd., Altitude Test Plant, Sinfin, Derby, 7 p.m. ★ LONDON GRADUATES' BRANCH: Visit to the Thames Board Mills, Purfleet, Essex, 2.30 p.m. ★ SCOTTISH GRADUATES' BRANCH: Visit to the studios of Scottish Television, Ltd., Glasgow, 7.30 p.m. ★ SOUTHERN GRADUATES' BRANCH: College of Technology, Anglesea Road, Portsmouth, Chairman's Address, "Planned Maintenance in a Light Engineering Plant," M. Haward, 6.30 p.m.

Wed., Feb. 1.—EDUCATION GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "The Selection and Progress of Engineering Undergraduates in Universities," opened by D. G. Christopherson, 6 p.m. ★ YORKSHIRE BRANCH: The University, Sheffield, "Avoidance of Failures," G. A. Cottell, 6.30 p.m. ★ EAST MIDLANDS GRADUATES' BRANCH: College of Further Education, Loughborough, "The Behaviour of Thick Walled Cylinders under Pressure," G. J. Franklin, 7.15 p.m.

Thurs., Feb. 2.—EASTERN BRANCH: Clarendon Laboratory, Oxford, "Controlled Fusion," A. Folkierski, 7.30 p.m. ★ EAST MIDLANDS BRANCH: Royal Hotel, Grimsby, "Present Day Feed Water Treatment for High Pressure Boilers," P. Hamer, 7.30 p.m. ★ SCOTTISH BRANCH: Royal College of Science and Technology, Glasgow, Repetition of the Graham Clark Lecture, "The Engineer and Civilisation," Sir Hugh Beaver, 7.30 p.m. ★ SOUTHERN BRANCH: Technical College, Farnborough, "Some Engineering Problems in Aeronautics," D. G. A. Rendel, 7.30 p.m. ★ YORKSHIRE GRADUATES' BRANCH: Grand Hotel, Sheffield, "Work Study," N. H. McLean, 6.30 p.m.

Fri., Feb. 3.—SCOTTISH BRANCH: Technical College, Dundee, Repetition of the Graham Clark Lecture, "The Engineer and Civilisation," Sir Hugh Beaver, 7.30 p.m.

Mon., Feb. 6.—NORTH EASTERN BRANCH: Neville Hall, Westgate Road, Newcastle upon Tyne, Repetition of the Thomas Lowe Gray Lecture, "The Early Developments of the Dracone Flexible Barge," W. R. Hawthorne, 6 p.m.

INSTITUTION OF MINING ENGINEERS

To-day, Jan. 27.—Royal Institution of Naval Architects, 10, Upper Belgrave Street, London, S.W.1, Sixty-Seventh Annual General Meeting, 11.15 a.m.

INSTITUTION OF PLANT ENGINEERS

To-day, Jan. 27.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Power Factor Correction of Electrical Plant," G. Hoyland, 7.30 p.m.

Mon., Jan. 30.—WEST AND EAST YORKSHIRE BRANCH: Houldsworth School of Applied Science, The University, Leeds, "The Uses of Molybdenum Disulphide," G. J. Vineall, 7.30 p.m.

Wed., Feb. 1.—EDINBURGH BRANCH: 25, Charlotte Square, Edinburgh, "Engineering in the Petroleum Industry," W. M. Greenhorn, 7 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Jan. 27.—NORTH MIDLANDS REGION: Louis Room, St. James Restaurant, Derby, "The Manufacture of a Motor Car," G. Irvin, 7 p.m.

Mon., Jan. 30.—NORTH WESTERN REGION: Reynolds Hall, Manchester College of Science and Technology, Manchester, "The Design of Bluebird," D. Stevens, 7.15 p.m.

Wed., Feb. 1.—NORTH MIDLANDS REGION: Reform Club, Victoria Street, Nottingham, "Lubricants in Manufacturing Processes," W. G. Medlock, 7 p.m.

Thurs., Feb. 2.—SOUTH EASTERN REGION: Royal Commonwealth Society, London, "Materials Handling in Production Processes and Stores," R. G. Winton, 7 p.m. ★ ROCHESTER GRADUATE SECTION: Sun Hotel, Chatham, "Manufacture and Application of Ball and Roller Bearings," T. S. Nisbet, 7.30 p.m.

Mon., Feb. 6.—NORTH WESTERN REGION: Reynolds Hall, Manchester College of Science and Technology, Manchester, "Production Engineering Research in the Soviet Union," R. Tilsley, 7.15 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Thurs., Feb. 2.—HUMBERSIDE SECTION: Yarborough Hotel, New Holland, "Colouring in Rubber," C. Musgrave, 8 p.m. ★ SOUTHERN SECTION: The University, Southampton, "The First Year of Operation of the Free Trade Area with Particular Reference to Rubber and Plastics," L. L. Gordon, 7.30 p.m.

Mon., Feb. 6.—BURTON-ON-TRENT SECTION: Midland Hotel, "Rubber in Astronautics," and Film "Rubber in Space Research," N. H. Longton and W. H. Stevens, 7.30 p.m. ★ NORTH EASTERN SECTION: Eldon Grill, Newcastle, Debate and Brains' Trust, 7 p.m. ★ SOUTH WALES AND MONMOUTHSHIRE SECTION: Queens Hotel, Cardiff, "Motor Car and Motor Cycle Racing," A. T. Walsham, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Jan. 27.—MIDLAND COUNTIES BRANCH: Byng Kenrick Suite, College of Advanced Technology, Gosta Green, Birmingham, 6, "The Structural Engineer in the Field of Atomic Energy," T. C. Waters, 6.30 p.m.

Wed., Feb. 1.—WALES AND MONMOUTHSHIRE BRANCH: Mackworth Hotel, High Street, Swansea, "The Planning and Design of the Central Market, Swansea," H. Menders and J. M. Burke, 6.30 p.m.

Thurs., Feb. 2.—WALES AND MONMOUTHSHIRE BRANCH: South Wales Institute of Engineers, Park Place, Cardiff, "Multi-Storey Car Parks," E. C. Roberts, 6.30 p.m.

Fri., Feb. 3.—WESTERN COUNTIES BRANCH: Small Lecture Theatre, University Engineering Laboratories, University Walk, Bristol, 8, Forum, 6 p.m. ★ MIDLAND COUNTIES GRADUATES' AND STUDENTS' SECTION: Engineering Centre, Stephenson Place, Birmingham, "Structural Engineering in the Construction of the Inner Ring Road," S. G. Piggot, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Jan. 27.—Pepys House, 14, Rochester Row, London, S.W.1, "Pingon Tower Cranes and their Applications," A. H. Davies, 7 p.m.

Wed., Feb. 1.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Industrial Insurance," B. Chellingworth, 7 p.m.

Fri., Feb. 3.—Pepys House, 14, Rochester Row, London, S.W.1, Films, 7 p.m.

NEWCOMEN SOCIETY

Wed., Feb. 1.—Lecture Theatre, Science Museum, London, S.W.7, "The Draining of the Alport Lead Mines, Derbyshire," Nellie Kirkham, 5.30 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Jan. 27.—Lecture Theatre, Mining Institute, Neville Hall, Newcastle upon Tyne, "Marine Steam Turbine Design and Operation," A. F. Veitch, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., Jan. 31.—SCOTTISH BRANCH: St. Enoch Hotel, Glasgow, "Lift Slab Design and Construction," F. R. Benson, 6.30 p.m.

Mon., Feb. 6.—NORTH WESTERN BRANCH: Liverpool Engineering Society, The Temple, 24, Dale Street, Liverpool, "Lift Slab Design and Construction," F. R. Benson, 6.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Wed., Feb. 1.—AGRICULTURAL AVIATION GROUP: Lecture Theatre, 4, Hamilton Place, London, W.1, "The Economics of Agricultural Chemicals and Fertilisers," J. C. Pinder, 7 p.m.

Thurs., Feb. 2.—SWINDON BRANCH: The College, Victoria Road, Swindon, "Nuclear Propulsion for Aircraft," A. D. Baxter, 7.30 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Feb. 6.—12, Great George Street, Westminster, London, S.W.1, "Share Valuations: Why and How," T. A. Hamilton Baynes, 5.45 p.m.

ROYAL INSTITUTION OF NAVAL ARCHITECTS

Thurs., Feb. 2.—10, Upper Belgrave Street, London, S.W.1, "Sea Trials on Two Cross-Channel Twin-Screw Ships," G. Aertssen, 4.45 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Fri., Feb. 3.—ROAD AND BUILDING MATERIALS GROUP: Robinson Theatre, The University, Manchester, "Surface Active Agents in Bituminous Road Materials," D. H. Mathews, 6.30 p.m.

SOCIETY OF ENGINEERS

Mon., Feb. 6.—Geological Society, Burlington House, London, W.1, Presidential Address, W. E. Humphrey, 5 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., Jan. 31.—Manson House, 26, Portland Place, London, W.1, "Instrumentation Past, Present and Future," L. S. Yoxall, 6.30 p.m.